

Mulga Downs

Groundwater, Surface Water & Ecohydrological Studies

Baseline Assessment

Prepared for:

HanRoy Iron Ore Pty Ltd

March 2025

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DOCUMENT STATUS

Version	Purpose of Document	Author	Reviewed By	Review Date
A	For Client Review	EJB / MAN	DGS	4/10/24
B	Final	EJB / MAN	DGS	13/11/24
C	Final	EJB / MAN	DGS	19/12/24
D	March 2025 EPA comments addressed	EJB / MAN	DGS	27/3/25

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Version:	D		
Date:	27 March 2025		
AQ2 Ref:	F:\171\3.C&R\Reports\492_Combined Baseline\171X_492c.docx		

EXECUTIVE SUMMARY

HanRoy Iron Ore Projects Pty Ltd (HanRoy) on behalf of Hancock Prospecting Pty Ltd (HPPL) is proposing to develop the Mulga Downs Iron Ore Mine (the Project) located approximately 210 km south of Port Hedland and 180 km northwest of Newman, in the Pilbara Region of Western Australia. The proposed Mulga Downs Hub and Rail Spur Project is a separate, standalone project as it is intended to be constructed and operated independently to the Mulga Downs Iron Ore Mine and is not considered in this assessment.

The Project encompasses the Murray's Hill and Mulga East Deposits within the Mulga East tenement (currently Retention Licence R47/12, with Mining Lease M47/1621 pending), with no development proposed over the adjacent / nearby exploration tenements of Malay Well (E47/2117) and Mulga West (E47/1315). However, for the purpose of these water and ecohydrological studies, the Study Area comprises the Mulga East and Malay Well tenements and areas of the Development Envelope which extend outside of these tenement boundaries. The Study Area represents the area within which baseline data has been collected, with additional ecohydrological assessments and limited (preliminary) groundwater investigations undertaken on the Mulga West tenement.

The proposed Project comprises seven mining areas (from west to east): Murray's Hill, Anticline Hill, Fridge West, Fridge Central, Fridge Hill, Horseshoe West and Horseshoe Hill. Approximately 20 of the pits are proposed to extend (to varying depths) below the groundwater level and will therefore require dewatering. The lowest estimated pit elevation is 388 mRL (i.e. ~12 to 16 m below the groundwater level).

The mine area is located on the northern slopes of the Fortescue Valley, within the Goodiadarrie Swamp catchment, which includes the Koodjeepindarranna and Gnalka Gnoona freshwater claypans plus other intermittent areas of surface water pooling.

AQ2 has undertaken baseline groundwater, surface water and ecohydrological studies to develop an integrated conceptual model for the Study Area, with specific focus on the culturally and environmentally sensitive wetlands of the Fortescue Valley, inclusive of the Gnalka Gnoona and Koodjeepindarranna Claypans. The conceptual model and natural (i.e. pre-mining) baseline are summarised below.

Conceptual Model

Between 2018 and 2023 a total of 80 monitoring bores and 12 test production bores have been installed across the Mulga East, Malay Well and Mulga West tenements with hydraulic testing conducted on ten of the production bores to date and the majority of the monitoring bores. In addition, eight surface water monitoring stations have been installed (six within creek channels upstream of the Koodjeepindarranna and Gnalka Gnoona Claypans and two within the claypans themselves). Baseline groundwater and surface water monitoring has been undertaken since early 2019. It is noted that the Baseline data collection period commenced at the tail end of a significant drought in the area, which followed a sustained period of high annual rainfall totals in the Pilbara. During the Baseline period, no large, rare rainfall events have occurred.

Further field investigations have comprised ecophysiological measurements of vegetation (three dry season and one wet season programmes) at multiple locations in the Mulga East, Malay Well and Mulga West tenements and ecohydrological site inspections over the Mulga East and Malay Well tenement areas; with the latter comprising observations of hydrological features, geomorphology as well as vegetation composition and structure.

All field data from the drilling, testing and monitoring programmes have been combined with findings from previous hydrogeological investigations and groundwater level monitoring data dating back to 2008 to develop the conceptual hydrogeological model for the area. Whilst 2D flood modelling and claypan water balance modelling has been completed to assist in the development of a conceptual hydrological model for the area. Salient points regarding the current understanding of the hydrogeological / hydrological system are as follows:

- The Study Area is fully contained within the Fortescue Valley catchment, with Goodiadarrie Swamp located immediately to the south of the site. Runoff from smaller rainfall events is likely to be contained within the Goodiadarrie Swamp area, with discharge into the Lower Fortescue River likely to require larger rainfall events.

  The Koodjeepindarranna and Gnalka Gnoona Claypans have catchments that drain from both the north (Chichester Range) and the south (Hamersley Range) reporting to them. Very little transfer of water along the valley floor within the Goodiadarrie Swamp area is thought to occur, with no defined preferred drainage paths along the valley floor and a valley floor slope of ~0.01% (10 m elevation fall over 80 km length). Baseline surface water flood modelling has been used to assist in the definition of the claypan catchment areas, which vary depending on the magnitude of the rainfall event. Based on water level monitoring data collected across the site, it appears that rainfall events exceeding a rainfall depth of 35 mm are required to generate runoff in the Chichester Range drainage lines and 90mm of rain to result in inundation in the claypans. Inundation within the claypans appears to occur frequently and it is likely that hydrologic responses from average, relatively frequent rainfall events are important in maintaining ecosystem function at the claypans (i.e. ecosystem function does not just rely on high magnitude low frequency runoff events). The low salinity of the ponded water within the claypans and the recorded depth to groundwater below the claypans indicates that the water is sourced from surface water runoff. Comparing the observed water level recession in the claypans from recent rainfall events to evaporation data indicates that evaporation plays the primary role in removing collected water from the claypans, with only minor seepage to the groundwater system. Residual salts from this evaporative loss are leached into the groundwater system under the claypans by the small component of seepage. Over time, this is thought to have resulted in saline groundwater beneath the claypans.
- The groundwater system is hosted in predominantly high permeability bedrock and valley fill, with the only low permeability aquitards being the fresh dolomite of the Wittenoom Formation underlying the valley area and the fresh Jeerinah and Marra Mamba Formations that underlie the orebodies and outcrop along the northern boundary of the Study Area. Secondary permeability resulting from mineralisation, fracturing and weathering, is evident throughout most of the Marra Mamba Formation and the overlying West Angela Member; these units are in hydraulic connection and are believed to form a transmissive basement aquifer. Although no faults have been mapped in the area to date, it could be that this basement aquifer has a lower bulk-permeability than currently adopted with a compensatory increased permeability along particular fault lines. Additionally, it is anticipated that faulting in the Malay Well area has resulted in complexities which are not represented in the current geological model.
- The valley fill has been categorised into the following units: Basal Crete, Pisolite / CID, Undifferentiated Tertiary (inclusive of alluvial fans and scree on the valley flanks) and Upper Calcrete. Although the composition and nature of these units are variable, derived permeabilities are generally high for all the units, with only limited intervals of low permeability clay which do not seem to be continuous.
- The transmissive nature of the bedrock and valley fill is reflected in the low hydraulic gradient observed across the orebody area and valley area, with a steeper gradient only evident along the northern boundary of the Study Area (across the low permeability Jeerinah Formation). Groundwater flow generally follows the topography, flowing from the higher elevations into the valley and then in a northwesterly direction along the valley. The depth to groundwater is shallow in the lower lying, valley

areas (i.e. approximately 3 to 5 mbgl) and increases with elevation, to depths of up to 45 mbgl in the more elevated areas.

- Groundwater across the Study Area ranges from fresh (180 mg/L TDS) in the upper reaches of the groundwater system, to saline (17,000 mg/L TDS) across the valley area, with salinity profiling data confirming saline groundwater originating from the claypans and extending along the valley as well as beneath the orebodies closest to the claypans (although the mining of these orebodies is not part of the proposed mine plan).
- Recharge to the groundwater system occurs as diffuse recharge from rainfall events, both on the valley flanks where the Marra Mamba outcrops and as infiltration into the Tertiary / Quaternary overburden where runoff is focused on the valley floor.

The findings of the ecohydrological site inspection, combined with remote sensing data and available vegetation mapping and soil assessments was used to evaluate the ecohydrological behaviour of the landscape and define ecohydrological units (EHUs) for the Study Area. Table ES1 summarises the key elements and functional aspects of each EHU.

A detailed ecohydrological baseline assessment of the Fortescue Valley environs has also been undertaken, involving characterisation of major vegetation types and evaluation of the ecological water requirements of the E. victrix woodland communities. The potential groundwater dependence of vegetation in the Fortescue Valley has been evaluated using seven assessment tools outlined in the Australian groundwater-dependent ecosystems toolbox (Richardson et al. 2011). It is concluded that groundwater dependent vegetation does not occur in the Study Area, based on the following supporting evidence:

- Groundwater underlying the Fortescue Valley environs is generally brackish/saline and therefore does not constitute a favourable water source for floodplain vegetation.
- Regolith characteristics in the Fortescue Valley environs suggest that vegetation rooting depth is impeded by massive calcrete or dense, low permeability clay layers. Owing to access and ground disturbance constraints due to heritage values in these areas, direct observation of tree roots were limited to several sump pits associated with hydrogeological drilling.
- Across the Study Area, there are no areas of persistently high greenness as measured by time series NDVI imagery.
- Time series pre-dawn leaf water potentials indicate the tree-root zones are in unsaturated media with widely varying soil matric pressure, that is generally lower (i.e. more negative) than -0.5 MPa. Also taking into consideration the potential influence of brackish groundwater, this precludes the roots being in groundwater or at the capillary fringe.
- Based on water balance modelling supported by on-ground vegetation measurements (i.e. woodland tree size and density), surface water inputs were calculated to be sufficient to support the density of trees occurring in the Fortescue Valley E. victrix woodland communities. The more dense woodland stands are associated with better structured soils with relatively higher plant-available water storage capacity.

Table ES1 Summary of Landscape Ecohydrological Units in the Area of Interest

	EHU	Summary description	Hydrological behaviour
Chichester Range Uplands	Upland Rises	Peaks and upper hillslopes; shallow or skeletal soils overlying basement rocks.	Runoff source areas – shed water to downgradient landscape units.
	Upland Valleys	Broader depressions in the Chichester Range where sediments have accumulated, facilitating runoff capture/storage and denser vegetation.	Local sink area, receiving diffuse flow from Upland Rises Surplus from overtopping delivered into Upland Drainages.
	Upland Drainages	Single thread channels with cobble beds that traverse and exit the Chichester Range. Unconfined to semiconfined by hills of basement rocks. Channel beds mostly unvegetated with regular gravel bars and scour pockets. Scattered *E. victrix* trees in deeper soil pockets fringe the channels.	Transfer zones, receive runoff from upland catchments and transmit into Alluvial Fan Drainages.
	Basaltic Tablelands	Level to very gently inclined basaltic plains. Soils mostly comprise self-mulching cracking clays supporting tussock grassland communities.	Local sink area, receiving direct rainfall or locally distributed runoff
Alluvial Fans	Alluvial Fan Washplains	Banded vegetation (mulga and Snakewood) on a gently sloping stony plain. Runoff is generated in intergrove areas and mostly captured in the adjacent downslope grove.	Local sink area receiving rainfall. Surplus from overtopping delivered into Alluvial Fan Drainages.
	Alluvial Fan Drainages	Low sinuosity channels with narrow floodplains, collectively constituting drainage tracts, which dissect the Alluvial Fan Washplains. Supports relatively dense mulga shrubland.	Transfer zones, receive runoff from Upland Drainages and transmit into the Fortescue Valley.
Fortescue Valley Flats	Valley Calcrete Plains	Expansive unit of the Fortescue Valley. Variably dissected and overprinted by alluvium, giving rise to a subtle mosaic of benches, rises and depressions. Vegetation type and density related to soil depth, which is constrained by shallow calcrete (generally within 50 cm of the surface).	Benches and rises function as runoff source areas once internal storage is exceeded, shedding water to immediately adjacent units.
	Valley Stony Flats	Stony flats in the Fortescue Valley, generally on the valley margins where slope (and hence runoff) is insufficient to support banded vegetation. Prone to accumulation of salts due to poor infiltration; only sparsely vegetated. These areas support transient but not persistent ponding.	Receive inflows from Alluvial Fan Drainages. The flat stony pavement surfaces function as runoff source areas once internal storage is exceeded, shedding water to immediately adjacent units.
	Valley Loamy Flats	Broad flats typically inset from the valley margins, where accumulated sediment and organic matter create better soil structure and high infiltration rates. Relatively deep soils (may exceed 100 cm). High surface roughness contributes to some localised surface water redistribution within the unit. These areas support dense patches of woodland and grassland vegetation; with vegetation types related to subtle changes in physical and chemical soil properties.	Predominantly sink areas that receive runoff from adjacent units (Valley Stony Flats and Calcrete Plains). Overtopping is uncommon and associated with large cyclonic rainfall events.
	Valley Ponding Flats	The lowest depressions in the Fortescue Valley where water ponds; typified by high clay content topsoil that impedes infiltration. Prone to accumulation of salts due to poor infiltration; only sparsely vegetated. These areas support persistent ponding.	Sink areas that collect rainfall and receive runoff from adjacent units (Valley Stony Flats and Calcrete Plains, and more rarely Loamy Flats).

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TABLE OF ABBREVIATIONS

Abbreviation	Definition
2D	Two dimensional
ACH	Aboriginal Cultural Heritage
AEP	Annual Exceedance Probability
AMD	Acid Mine Drainage
ANZECC	Australian and New Zealand Environment and Conservation Council
AR&R	Australian Rainfall and Runoff
ARI	Annual Recurrence Interval
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
BoM	Bureau of Meteorology
DEM	Digital Elevation Model
DPLA	Department of Planning, Lands and Heritage
DWER	Department of Water and Environmental Regulation
EC	Electrical Conductivity
ESA	Environmentally Sensitive Area
EPA	Environmental Protection Authority
HEC-RAS	Hydrologic Engineering Center's River Analysis System
HPPL	Hancock Prospecting Pty Ltd
IFD	Intensity-Frequency-Duration
IL	Initial Loss
km	Kilometre
LiDAR	Light Detection and Ranging
LOM	Life of Mine
l/s	Litre per second
m	Metre
MAR	Managed aquifer recharge
Max	Maximum
mbgl	Metres below ground level
mbRP	Metres below reference point
mbTOC	Metres below top of casing
MDEC	Mulga Downs Exploration Camp
mg/l	Milligram Per Litre
mm	millimetre
mRL	Metres Relative Level
µS/cm	Micro Siemens per cm
NASA	National Aeronautics and Space Administration
ND	Nominal Diameter
PAF	Potentially Acid Forming
PEC	Priority Ecological Community
PL	Proportional Loss
RFFE	Regional Flood Frequency Estimate
RFFP	Regional Flood Frequency Procedure
ROM	Run of Mine
RORB	Runoff Routing
SCL	Stochastic Climate Library
SWL	Static Water Level
SWML	Surface Water Monitoring Location
SRTM	Shuttle Radar Topography Mission
TDS	Total Dissolved Solids
V	Volt
WRD	Waste Rock Dump

1. BACKGROUND

1.1 Introduction

HanRoy Iron Ore Projects Pty Ltd (HanRoy) on behalf of Hancock Prospecting Pty Ltd (HPPL) is proposing to develop the Mulga Downs Iron Ore Mine (the Project) located approximately 210 km south of Port Hedland and 180 km northwest of Newman, in the Pilbara Region of Western Australia. The Project encompasses the Murray's Hill and Mulga East Deposits within the Mulga East tenement (currently Retention Licence R47/12, with Mining Lease M47/1621 pending), with no development proposed over the adjacent / nearby exploration tenements of Malay Well (E47/2117) and Mulga West (E47/1315). A location plan is provided as Figure 1.1, showing these tenements. Although other HPPL tenements cover the Project Development Envelope, these have not been shown.

The proposed open cut pit footprints, referenced as MDE_LOM_20_F_20240805 (MDE_LOM_20), are shown in Figure 1.2, together with the indicative Project layout. The pit footprints comprise seven mining areas (from west to east): Murray's Hill, Anticline Hill, Fridge West, Fridge Central, Fridge Hill, Horseshoe West and Horseshoe Hill. Approximately 20 of the pits are proposed to extend (to varying depths) below the groundwater level and will therefore require dewatering. The lowest estimated pit elevation is 388 mRL (i.e. ~12 to 16 m below the groundwater level).

AQ2 has been engaged to undertake baseline groundwater, surface water and ecohydrological studies and impact assessments, to support the environmental assessment of the Project. This report details all baseline and conceptualisation work undertaken from 2018 until November 2023, with impact assessments documented in a standalone Groundwater and Surface Water Impact Assessment Report (AQ2 2024). Subterranean fauna studies have also been conducted as part of the baseline investigations and have been documented separately in standalone reports.

The Study Area is defined for this report as the area shown in Figure 1.2 which includes the Mulga East and Malay Well tenements and areas of the Development Envelope which extend outside of these tenement boundaries. The Study Area represents the area within which baseline data has been collected, with additional ecohydrological assessments and limited (preliminary) groundwater investigations undertaken on the Mulga West tenement (refer to Figure 1.1). Some of the assessments completed within this report (such as flood modelling and the delineation of ecohydrological units) extend beyond the limits of the Study Area.

HPPL are proposing the Mulga Downs Hub and Rail Spur Project as a standalone project as it is intended to be constructed and operated independently to the Mulga Downs Iron Ore Mine. Baseline assessments related to the Hub and Rail Spur Project are not presented in this report.

1.2 Objectives

The primary objective of this Baseline Assessment Report is to support the environmental impact assessment of the Project. As such, the objectives comprise:

- Defining a baseline hydrological data set that quantifies the hydrological characteristics of the ecohydrological systems.
- Formulating conceptual models for the local and regional eco-hydrological systems.
- Identifying environmental assets that may be impacted by hydrological change resulting from the Project (receptors) and quantifying their baseline hydrological behaviour.

1.3 Climate

The climate of the Study Area is described as semi-arid, characterised by hot summers, with maximum monthly temperatures often exceeding 40°C, and milder winters. Rainfall is highly variable, but on average about 75% of annual rainfall is received between December and March, in association with thunderstorms and cyclonic events. Climate is discussed in more detail in Section 2.

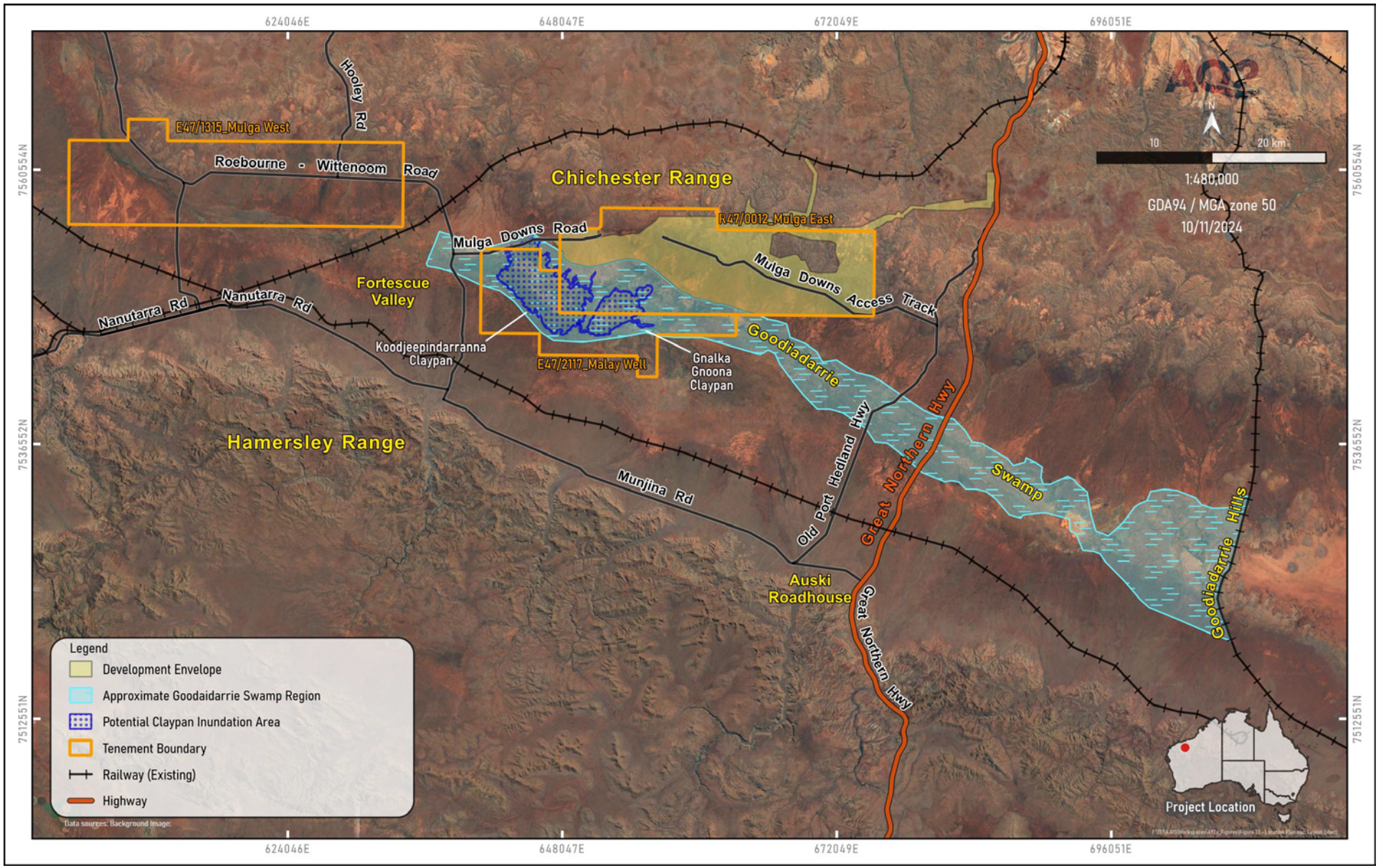


Figure 1.1 Location Plan

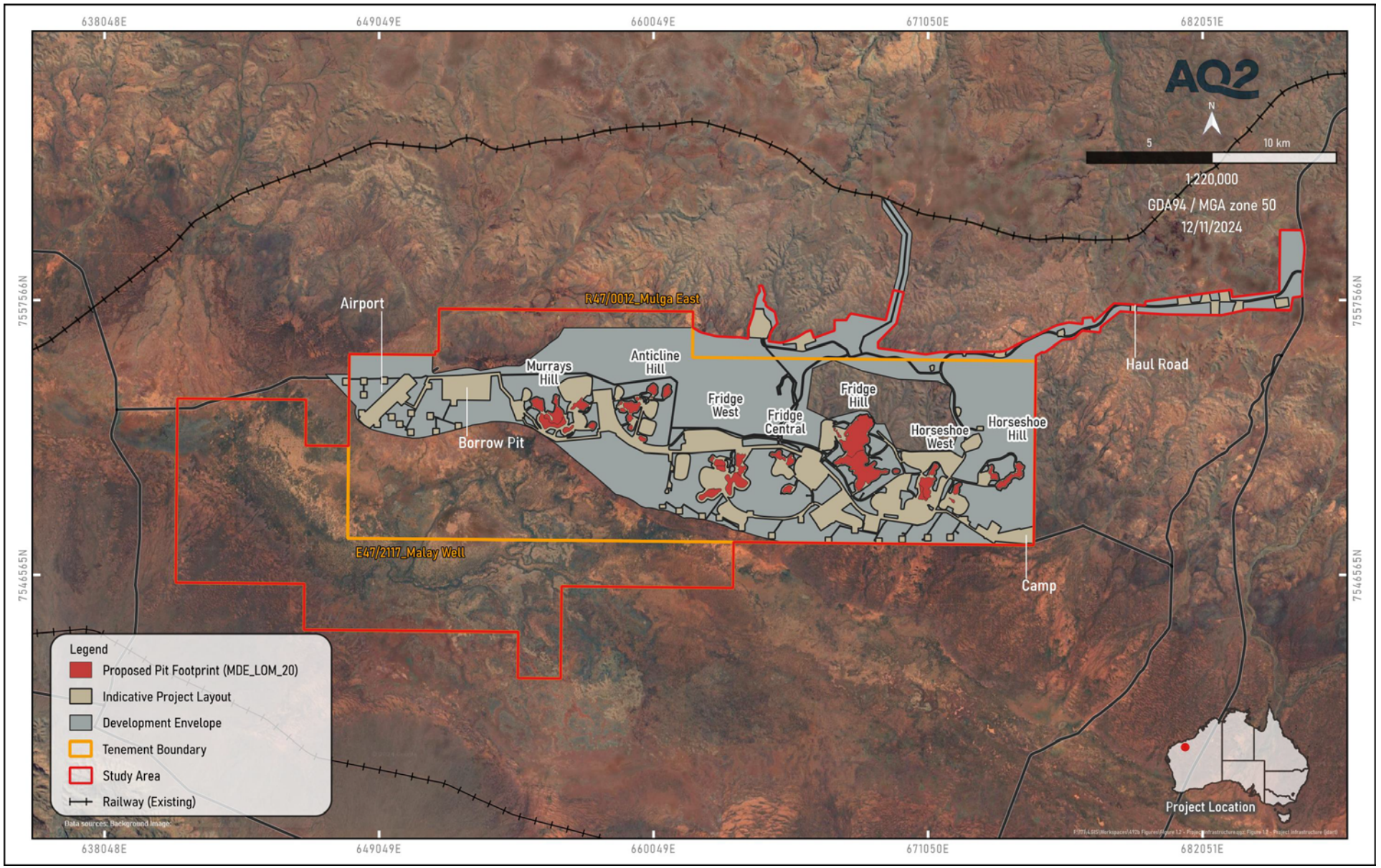


Figure 1.2 Indicative Project Layout

1.4 Physiography

The Study Area is located within the Chichester Range, on the northern flanks of the Fortescue Valley (refer Figure 1.1). The Chichester Range comprises low-lying hills which rise approximately 100 m above the level of the Fortescue Valley floodplain. The hills are cross-cut by narrow, steep-sided gullies, with colluvium and alluvial fans extending from the hills across the valley floor where drainages flow into the Fortescue Valley.

Within the vicinity of the Study Area, the Fortescue Valley comprises a network of interconnected ephemeral swamps, claypans and floodplains (collectively, an area known colloquially as Goodiadarrie Swamp), with the valley floor gently sloping in a westerly direction. The valley is some 20 km wide and is bound to the south by the Hamersley Range.

1.5 Regional Hydrology

The Fortescue Valley is split by the Goodiadarrie Hills (a ~5 m barrier that forms a surface water divide) into the (eastern) Fortescue Marsh and the (western) Goodiadarrie Swamp (refer Figure 1.1). The Fortescue Marsh (approximately 60 km to the east) is the largest ephemeral wetland in the Pilbara region and is recognised as a nationally important wetland. A second surface water divide exists to the west of the Goodiadarrie Swamp (immediately to the west of Koodjeepindarranna Claypan), separating the Goodiadarrie Swamp from the Lower Fortescue River.

1.6 Regional Geology

The bedrock within the Study Area comprises rocks of the Hamersley and Fortescue Groups (refer Table 1.1). The Jeerinah Formation (of the Fortescue Group) and Marra Mamba Iron Formation (Marra Mamba Formation) outcrop in the Chichester Range on the northern side of the Fortescue Valley. The Marra Mamba Formation and Wittenoom Formation subcrop beneath the valley floor within the Study Area, with the overlying Mt Sylvia Formation and Mt McRae Shale occurring to the south. The Brockman Iron Formation forms the Hamersley Range on the southern side of the Fortescue Valley (refer Figure 1.3). Tertiary and Quaternary deposits infill the valley. The Tertiary deposits are collectively referred as "detritals", comprising pisolite, clay and calcrete; there is also lateritic hardcap development of Tertiary age on basement rocks, which may be ferricrete (goethite) and calcrete / silcrete. The Quaternary deposits comprise alluvium and colluvium.

The mineralisation within the Study Area is primarily associated with the Nammuldi Member of the Marra Mamba Formation (that outcrops along the lower flanks of the Chichester Range), although there is also mineralisation in the overlying Tertiary detrital deposits.

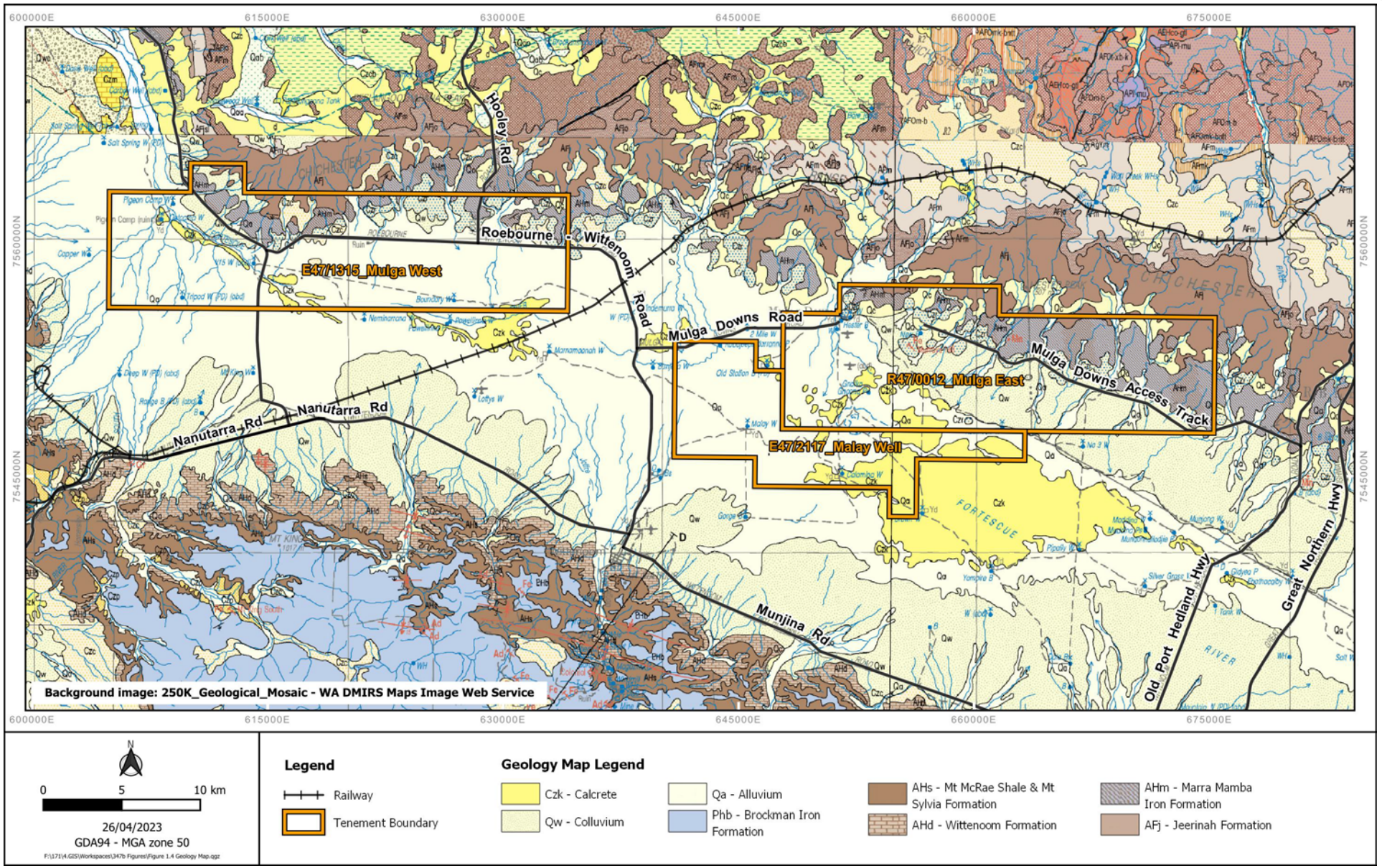


Figure 1.3 Geology Map

Table 1.1 Regional Stratigraphic Sequence within the Study Area

Group	Formation	Member	Lithological Description
Recent Alluvium / Colluvium			Unconsolidated silt, sand and gravel (clay near pans)
Tertiary Detritals (TD)	TD3		Red haematitic scree on valley sides. Increasing silt / clay content with distance from slopes / fans Increasing pisolitic content with depth
	TD2		Silcrete, calcrete (Oakover Formation), Channel Iron Deposit (CID), mottled clay
?*	?*	Pinjan Chert	Siliceous sediment with alternating laminated chert
Hamersley Group	Wittenoom Formation	Bee Gorge Member	Graphitic shale with minor sequences of carbonate, chert, volcaniclastic rock and Banded Iron Formation (BIF)
		Paraburdoo Member	Dolomite with minor amounts of chert and shale
		West Angela Member	Dolomite, dolomitic / manganese-rich shale, BIF and chert
	Marra Mamba Iron Formation	Mt Newman Member	BIF with minor shale
		MacLeod Member	Shale, chert and BIF
		Nammuldi Member	BIF, chert and shale
Fortescue Group	Jeerinah Formation	Roy Hill Shale Member	Dark grey to black graphitic shale with chert; locally pyritic
		Warrie Member	Grey dolomite with inter-bedded chert (locally ferruginous), shale and mudstone

*Age of the Pinjan Chert is uncertain

1.7 Native Title and Cultural Significance

The area covered by the water and ecohydrological studies is subject to two Native Title determinations (refer Figure 1.4). The Mulga East and Malay Well tenements fall within the native title area of the Banjima People, whilst the Mulga West tenement straddles the boundary of the Banjima People and Yindjibarndi People Native Title areas.

Mungurrdu (refer Figure 1.4) is a DPLH Aboriginal Cultural Heritage Lodged Place (ID:40484). The Banjima People are the Knowledge Holders for this place, it is culturally significant in multiple ways including as; a ritual and ceremonial area, a meeting place, a hunting place, a water source, and is associated with Creation/Dreaming stories. Banjima representatives first indicated to HanRoy the area had significant heritage values during a heritage survey in July 2023 before it was formally lodged as Mungurrdu with the DPLH in March 2024.

1.8 Land Use & Existing Groundwater Users

The Study Area lies within the administrative boundary of the Shire of Ashburton. The Mulga East and Malay tenements are wholly contained within the Mulga Downs pastoral lease area; whilst the Mulga West tenement is predominantly within the Mount Florence pastoral lease area; except for the western portion (circa 55 km^2) that intersects the northwest portion of the Mulga Downs pastoral lease and northeast fringe (circa 8.5 km^2) that intersects the Hooley pastoral lease (refer Figure 1.4). There is a long history of pastoral land use in the area, predominantly cattle grazing.

Existing groundwater users in the Study Area include the local and nearby stations (Mulga Downs, Hooley and Mt Florance Stations), for stock watering as well as the Wirrilimurra and Youngaleena Communities (refer Figure 1.5) and licenced water supplies associated with the construction of the existing FMG (Solomon) railway and RTIO (Goodiadarrie) railway.

1.9 Key Environmental Assets & Significant Fauna Habitat

Recognised conservation assets within and surrounding the Study Area, including identified Priority Ecological Communities (PECs), are summarised as follows, with spatial locations for those proximal to the Study Area shown in Figure 1.6:

- Freshwater claypans of the Fortescue Valley PEC (Priority 1) – this PEC includes a series of claypans in the Fortescue Valley, distributed over a distance of about 70 km from near the western end of the Fortescue Marsh to the Roebourne – Wittenoom Rd. The two westernmost claypans, known as the Gnalka Gnoona Claypan and the Koodjeepindarranna Claypan, are located in the Study Area (but outside the Development Envelope). The next claypan in the sequence moving east is the smaller Ebathcalby Claypan, located about 9 km south of the eastern margin of R47/12 (i.e. outside the Study Area). Note that the Koodjeepindarranna Claypan PEC buffer zone (based on Department of Biodiversity, Conservation and Attractions (DBCA) data set (DBCA 2020)) does not extend over the full ponding area which occurs during flooding of this claypan.

  DBCA surveys indicate that the wetlands of the Fortescue Valley may support over half of the aquatic fauna species present in the Pilbara (Pinder et al. 2017). Recognised values of and threats to the PEC include (DBCA 2022):

  - Values: Important for waterbirds, invertebrates and some poorly collected plants. *Eriachne* spp., *Eragrostis* spp. grasslands. A unique community with few *E. victrix* trees.
  - Threats: grazing, weed invasion, infrastructure corridors, altered hydrological flows, altered fire regimes.
- The four plant assemblages of the Wona Land System PEC (Priority 1 and 3), comprising a system of basalt upland gilgai plains with unusual grassland vegetation assemblages. The PEC occurs north of the Goodiadarrie Swamp sub-catchment divide and is therefore ecohydrologically disconnected from the proposed pit areas, however, the proposed haul road crosses through the PEC. Recognised threats include grazing, clearing for mining related activities and solar farms, altered fire regimes (DBCA 2022).
- Several small, persistent pools in or near the Study Area are considered to have potential local conservation significance including (refer Figure 1.6):
  - Channel pool within the Koodjeepindarranna Claypan complex. This was site P05A in the Pilbara Biological Survey (Pinder et al. 2010).
  - Channel pool at UTM Zone 50 653300E and 7550400N. Identified from aerial photography.
  - Channel pool at UTM Zone 50 661600E and 7547770N. Identified from aerial photography.
  - Gidyea pool south of the Study Area, proximal to the Ebathcalby Claypan – has significant wetland floor vegetation in contrast with claypans further to the west (Pinder et al. 2017).
  - Immediately upstream of the claypans, water ponding on the northern side of the valley and at the foot of the Chichester Range is apparent. This area partially corresponds with an Environmentally Sensitive Area (ESA) mapped by DWER. The proposed pit footprints are in excess of 1 km from this area.
- Also of note is the prominence of *Acacia stenophylla* in the Fortescue Valley floodplain woodlands within the Study Area. Although this species occurs across much of inland eastern Australia, the Fortescue Valley population is a major outlier from its core distribution.

- The Fortescue Marsh PEC (Priority 1) is located about 30 km to the east of the Great Northern Highway and about 60 km to the east of the Project mining areas. It consists of saline plains and lake beds some 100 km long, 5 to 20 km wide and occupying an area of approximately 1,000 km^2 (Markey 2017). The conservation values of the Fortescue Marsh are well recognised (EPA 2013). The marsh provides habitat for a variety of plant, invertebrate and vertebrate species of conservation significance. It has particular importance as a breeding and foraging habitat for waterbirds following flood events. In 2015, much of the land encompassing the marsh was excised from four pastoral leases and now constitutes the Fortescue Marsh Nature Reserve (Nyiyaparli Country), a Class A nature reserve. Forming the terminus of the Upper Fortescue Catchment, the marsh is considered to be hydrologically disconnected from the Study Area.
- A large portion of the Fortescue Valley including the Fortescue Marsh to the east of the Study Area is listed in the Directory of Important Wetlands in Australia[1] (DIWA066, Fortescue Marshes). As outlined in Section 1.8, the Fortescue Valley in the vicinity of the Project (including the freshwater claypans) is listed as a DPLH Aboriginal Cultural Heritage Lodged Place called Mungurrdu (ID:40484), shown on Figure 1.4.
- A number of threatened and migratory species listed under the *Environment Protection and Biodiversity Conservation Act 1999* and conservation fauna under the *Biodiversity Conservation Act 2016* have been identified as potentially utilising the habitats of the Study Area (DCCEEW 2023, JBS&G 2024a).

The Study Area does not contain any Threatened Ecological Communities (TECs) listed under the *Biodiversity Conservation Act 2016* or the EPBC Act.

[1] https://www.dcceew.gov.au/water/wetlands/australian-wetlands-database/directory-important-wetlands

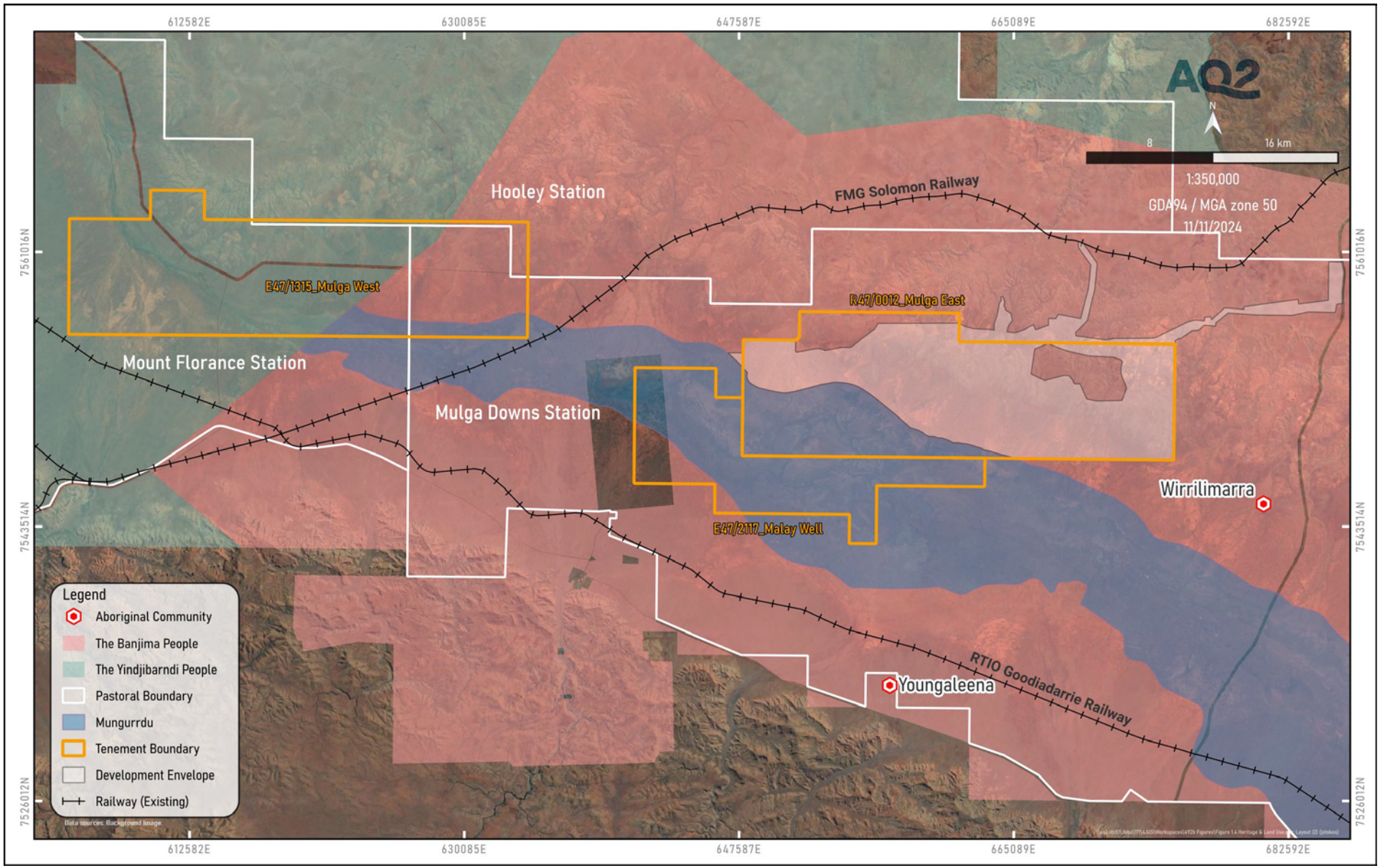


Figure 1.4 Pastoral & Native Title Boundaries

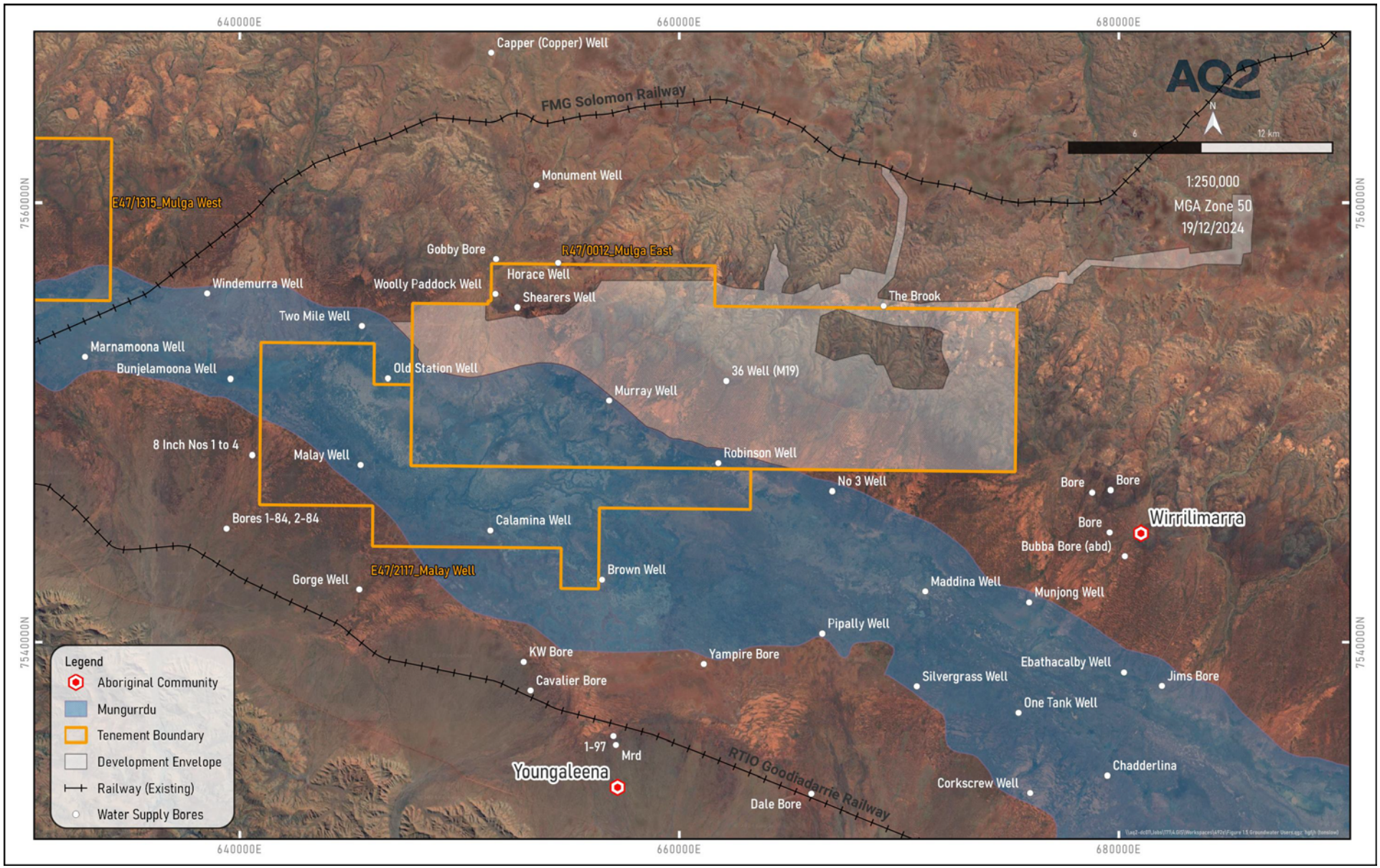


Figure 1.5 Groundwater Users

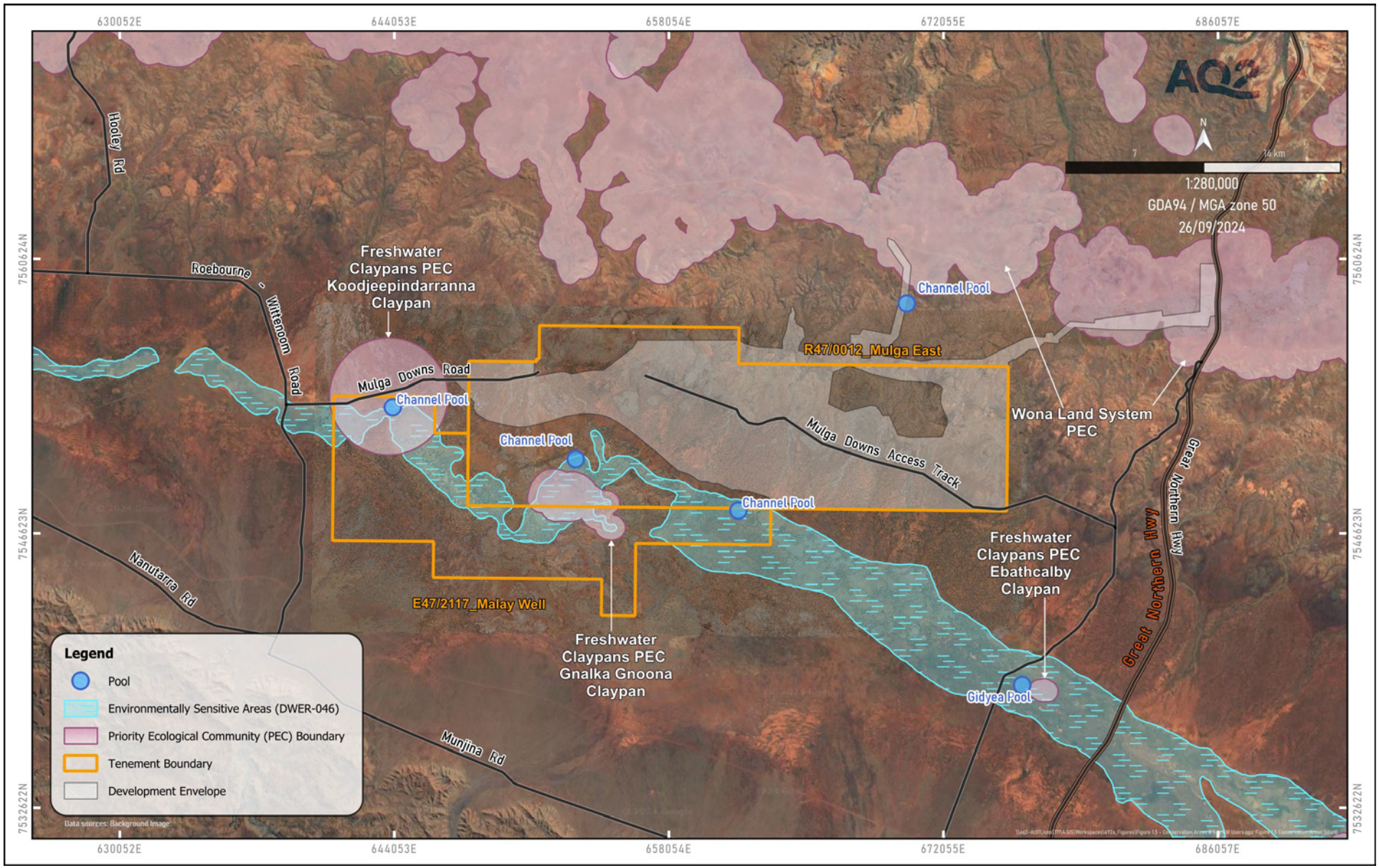


Figure 1.6 Conservation Areas

2. CLIMATE

2.1 General

The climate of the Pilbara is characterised by hot dry summers and mild winters (BOM 2024), with low average rainfall depths and highly variable rainfall. Based on mapping of the Koppen classification for climate (BOM 2024), areas within the Project location are classified as hot desert (winter drought) and hot grasslands (persistently dry).

Average daily maximum temperatures across the Pilbara are typically around 20°C in winter and exceed 30°C across the region in summer and early autumn. Average daily maxima temperatures tend to exceed 35°C from October to March and it is not uncommon to see temperatures more than 40-45°C.

Rainfall in the Pilbara is greatest during summer and autumn and least during winter and spring. It is spatially and temporally variable, with average annual rainfall totals ranging between 250-500 mm, the latter occurring in elevated areas such as the Hamersley Range situated south of the Project. Tropical cyclones, not uncommon to the Pilbara region, cause the most extreme rainfall events and generate 25–34% of the total annual rainfall near the Pilbara coast and as much as 21% up to 450 km inland (Sudmeyer 2016). Average monthly evaporation exceeds average monthly rainfall throughout the year.

The long-term average maximum daily temperature and annual rainfall at the Project is approximately 33°C and 355 mm respectively. A plot of the average minimum and maximum temperatures recorded at the Wittenoom weather station (now closed) and a comparison of average monthly rainfall to average monthly evaporation is shown in Figure 2.1.

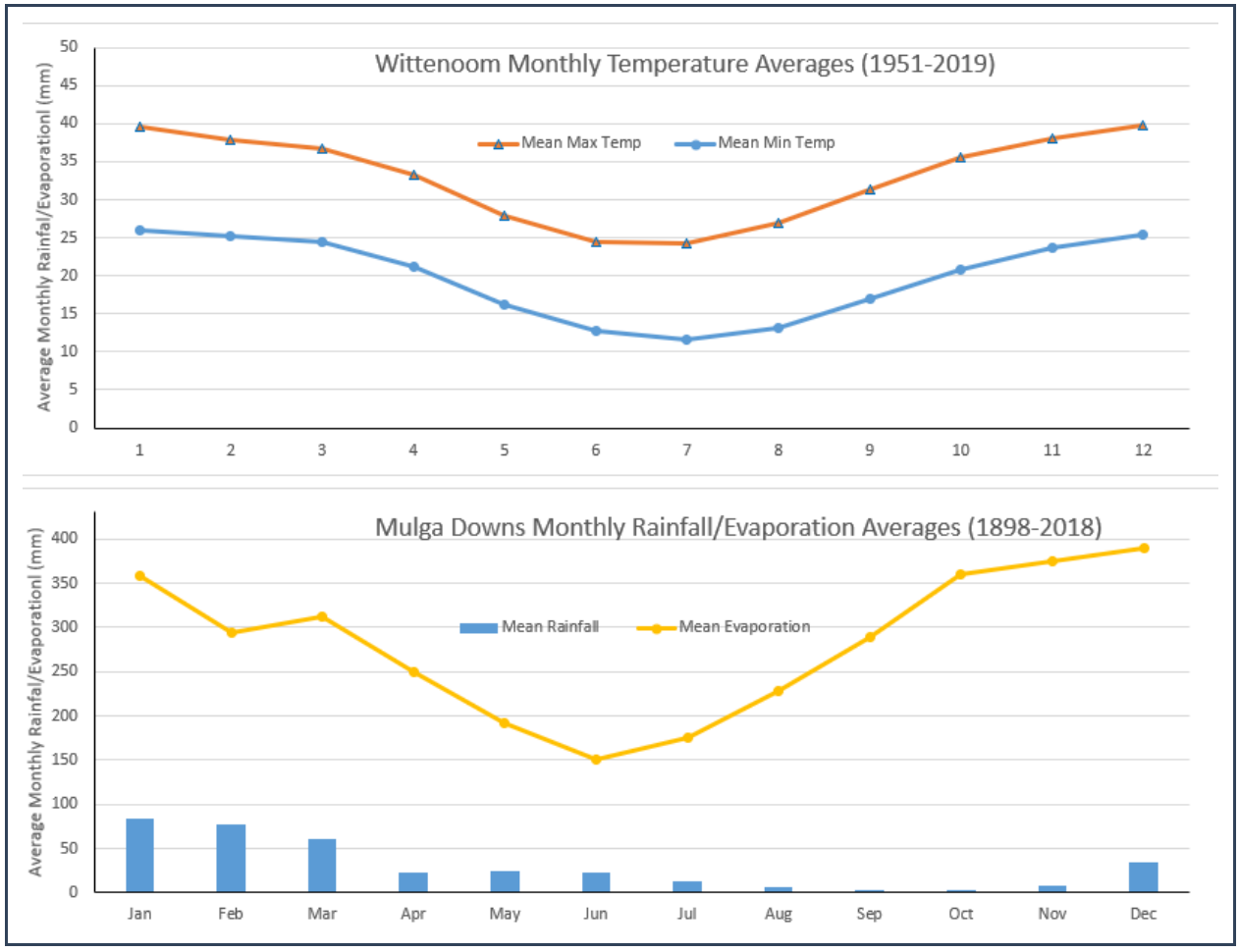


Figure 2.1 Mulga Downs Average Monthly Climate Data

2.2 Long Term Climate

In areas where measured rainfall data is sparse (spatially or temporally), interpolated rainfall data can be used from the Scientific Information for Land Owners project (SILO; Jeffrey et al. 2001). SILO provides gridded historic daily climate parameter estimates from 1889 to present, for any location in Australia to the closest 0.05° latitude/ longitude (decimal degrees).

An assessment of the long-term annual rainfall and maximum temperature totals for the Study Area has been undertaken using the SILO data for the period from 1900 to 2021, for locations -22.10 degrees south and 118.50 degrees east (Mulga East area) and -22.05 degrees south and 118.15 degrees east (Mulga West area). The data from each location were appraised to be materially similar (refer Table 2.1); as such climate data for the Mulga East area has been selected as representative of the Study Area and is plotted in Figure 2.2. Also shown is the cumulative deviation from the long-term average rainfall and temperature respectively. A deviation moving in an increasingly negative direction indicates drier (or cooler) than average conditions; an increasingly less negative (or positive) deviation indicates wetter (or hotter) than average conditions.

Three broad climatic periods can be defined:

- From 1900 until approximately 1970, there is an increasingly negative deviation from the long-term average rainfall, which indicates a dry period. There was a similarly increasingly negative deviation from the long-term average maximum temperature. Over this time only, average rainfall at Mulga East was 321 mm/year (compared with 359 mm/year as the long-term SILO average rainfall).
- For a circa 25-year period from 1970 to 1995, actual rainfall appeared to be close to the long-term average. Average rainfall at Mulga East over this period was 378 mm/year. Average maximum temperature was relatively stable.
- From 1995 to the present, the cumulative deviation became increasingly less negative indicating a wetter than average period. Average rainfall at Mulga East over this period was 445 mm/year. Maximum temperature shows a strongly increasing trend, and mean annual maximum temperature was 0.5^0C greater than preceding periods.

A Budyko model (Sposito 2017, Trancoso et al. 2016, Budyko 1974) was used to further investigate the energy/water balance for the Study Area, which controls the type of vegetation that can sustainably develop. Summary data for the Mulga East and Mulga West areas respectively are shown in Table 2.1. Of note:

- The aridity index (ratio of potential evapotranspiration to rainfall) varies depending on rainfall and temperature trends, but always falls within the 'arid' bandwidth.
- The Budyko model predicts that actual evapotranspiration (ET) in the Study Area is perpetually water-limited (not energy limited) despite varying rainfall inputs. Under these conditions, actual ET will approximate precipitation (i.e. almost all available water will be lost through evapotranspiration). This is consistent with the generally low rates of groundwater recharge in the Pilbara (McFarlane, 2015).
- Notwithstanding the water limitation, there is estimated to have been a significant increase (circa 25%) in actual ET due to the increased rainfall (when comparing the driest period between 1900 and 1970 and the wettest period between 1995 to current). Over this time scale, vegetation density would be expected to increase in response to increased ET (both in stem-size and leaf area of existing vegetation and in new vegetation recruitment). Thus, there are likely to have been significant changes in vegetation structure and density across the catchment over the last 100 years.

It is important to note that the Budyko estimates of actual ET (i.e. 312 to 443 mm; Table 2.1) represent a landscape scale average. In practice, actual ET will vary on a local scale and the following inferences can be drawn:

- For areas where ET is less than circa 440 mm/yr, site related limits on vegetation development can be inferred (such as constraints in substrate depth, soil quality, or infiltration capacity).
- For areas where ET is more than circa 440 mm/yr, additional plant-available-water can be inferred. This could arise from water transfers to vadose-zone storage through runoff accumulation and infiltration (e.g. such as from inundation of the claypans) and / or water-transfers from groundwater through phreatophytic water use. The storage capacity of the vadose zone is an important factor enabling vegetation utilisation of surface inflows.

Total ET (as estimated by the Budyko method) is a function of several individual components:

- Evaporation from open-water bodies in the Pilbara region is approximately 2,600 mm/yr; noting that this can be affected by site specific factors including solar shading, wind exposure, and humidity (Bourke et al. 2023; McJannet et al. 2017).
- Bare soil evaporation, which is most prominent immediately following rainfall / infiltration events and declines rapidly as the soil dries out. In a recent study in the Weeli Wolli catchment (east of the Study Area), weighing lysimeter measurements of soil evaporation were 0.2 and 0.7 mm/day during dry conditions (equivalent to around 80 – 240 mm/year) and 0.3 and 13.0 mm/day (average = 3.7 mm/day) during wet conditions (Tugwell-Wootton et al. 2020). Wet conditions only occur over short periods (days to weeks).
- Transpiration from vegetation, which is proportional to leaf area index (LAI), comprising:
    - Overstorey trees (e.g. *Eucalyptus victrix* in the Fortescue Valley). In woodlands and forests, overstorey trees dominate the vegetation LAI and hence transpiration flux.
    - Transpiration from understorey vegetation (e.g. grasses and small trees and shrubs such as *Acacia* spp. in the Fortescue Valley); which contribute to overall vegetation LAI. Some understorey species, particularly shallow rooted functional types, display seasonal water use behaviour (e.g. become dormant during dry phases).
    - Note that other factors such as soil fertility, bushfires, and cattle grazing can also influence vegetation LAI and transpiration flux.
- Interception losses comprising water intercepted and evaporated from vegetation canopies without reaching the soil surface. Higher interception losses are associated with denser vegetation. Based on global meta studies of rainfall interception in dryland vegetation types (Magliano et al. 2022)), interception by the Fortescue Valley *E. victrix* open woodlands is likely to be in the order of 5 - 10% of rainfall (i.e. about 20 to 40 mm/year).

Table 2.1 Long Term Climate Statistics (From SILO Data)

Period (Years)	Type Conditions (rainfall, temp)	PET (Morton's point potential)	Average Rainfall	Average Max. Daily Temp	Aridity Index	Budyko Actual ET Estimates (mm/yr)	Actual ET / Precipitation	ET var. from long term avg (%)
		(mm/yr)	(mm/yr)	^{0}C		Average	(%)	
MULGA EAST								
Long term average	Long-term	3,359	359	33.1	0.11	359	99.81%	0.0%
1900 - 1970	Dry, warm	3,375	321	33.0	0.09	320	99.85%	-10.8%
1971 - 1994	Average, warm	3,360	378	33.1	0.11	378	99.78%	5.3%
1995 - 2021	Wet, hot	3,319	445	33.6	0.13	443	99.67%	23.6%
MULGA WEST								
Long term average	Long-term	3,336	352	33.0	0.11	351	99.81%	0.0%
1900 - 1970	Dry, warm	3,343	312	32.8	0.09	312	99.85%	-11.2%
1971 - 1994	Average, warm	3,354	366	33.0	0.11	365	99.80%	4.0%
1995 - 2021	Wet, hot	3,301	443	33.5	0.13	442	99.67%	25.9%

Notes:

Aridity Index; based on United Nations Environment Programme Formula: $AI = \frac{Precipitation}{PET}$

Classification	Aridity Index
Hyperarid	AI < 0.05
Arid	0.05 < AI < 0.20
Semi-arid	0.20 < AI < 0.50
Dry subhumid	0.50 < AI < 0.65

Budyko estimates of Actual ET provide a catchment-wide average over multi-year timescales and are not representative of areas where water is "focussed"

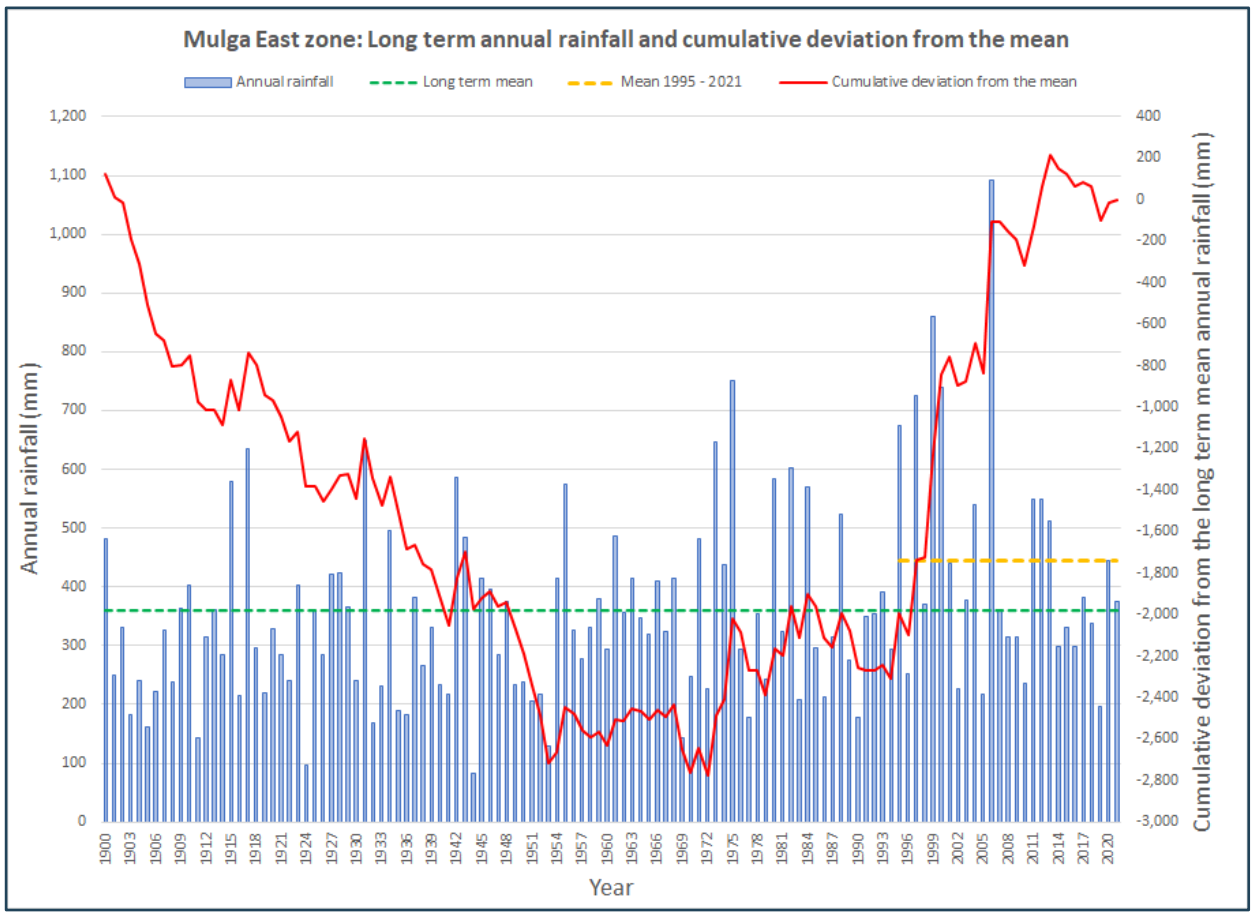
Overall average is derived from the SILO record over the period 1900 to 2021 and used as a baseline

ET variation is calculated by comparing average ET for a defined period against the long-term average

Type Conditions is a qualitative descriptor that describes the average rainfall and temperature for a defined period with respect to the long-term

Budyko Actual ET estimate is average of Budyko, Ol'Dekop and Schreiber methods (Li and Lu 2014)

Morton's point potential PET (Morton 1983) sourced from SILO database



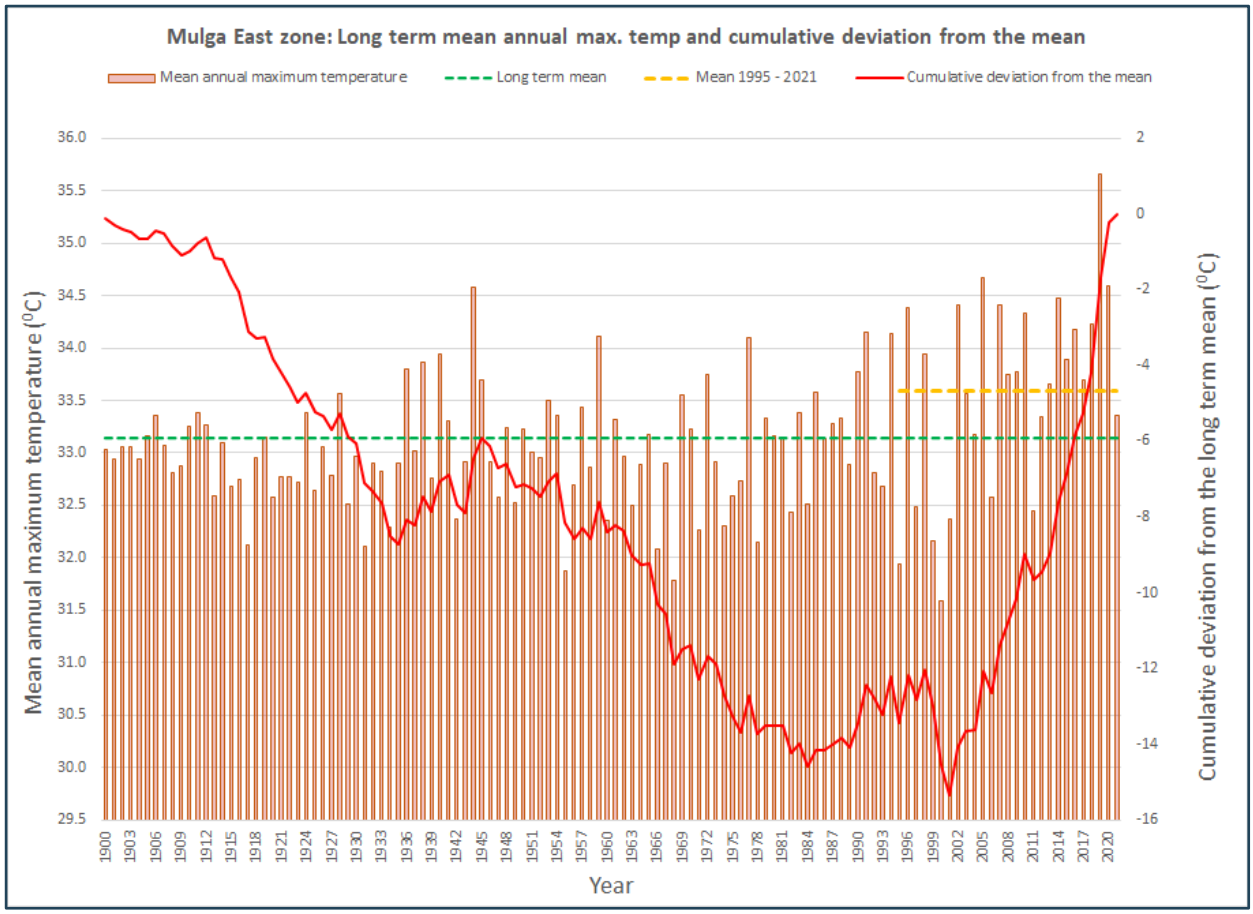


Figure 2.2 Time Series of Rainfall and Temperature at Mulga East

2.3 Recent Climate Trends

SILO rainfall data for the Study Area since 2012 is shown in Figure 2.3. Also shown is cumulative ETo (Penman-Monteith short crop reference evapotranspiration FAO56; Allen et al. 1998) between daily rainfall events greater than 25 mm, which approximates the rainfall threshold to generate significant runoff, creek flows and soil water replenishment. Notably 2019 was one of the driest years on record (198 mm) and also the hottest year on record (Figure 2.2). The rainfall data shows a prolonged period of soil water depletion and drought stress occurred between June 2018 and February 2020, which was not alleviated until a major rainfall event (93 mm) on 9 February 2020.

Further examination of drought trends was completed by using the Drought Indices Calculator (DrinC) (Tigkas et al. 2015; 2019; 2022) to calculate the Agricultural Standardized Precipitation Index (aSPI) for the period 1970 to present (Figure 2.4). The aSPI is a modification of the Standardised Precipitation Index (SPI), based on the substitution of the total precipitation by effective precipitation (P_e), which describes more accurately the fraction of precipitation that can be used productively by vegetation. Values for aSPI can be interpreted as standard deviations that the observed P_e deviates from the long-term mean. This analysis confirms that the 2018-19 drought was one of the most severe in the past 50 years, with other notable droughts occurring in 1976-77, 1978-79, 1985-86 and 2001-02.

In addition to seasonal variation in climate, heat wave frequency and severity has increased since the turn of the century (Figure 2.5). Heat waves can be characterised by consecutive days above a threshold percentile value for temperature and/or vapour pressure deficit. Vapour pressure deficit (VPD) is the difference (deficit) between the amount of moisture in the air and how much moisture the air can hold when it is saturated (Breshears et al. 2021). A threshold percentile value of 99.5% for the period 1975 to present was used to evaluate heat wave severity over this period; based on SILO climate data. This corresponded to maximum temperature greater than 45^0C and a VPD greater than 67 hPa. Extreme heat wave events were identified to occur in February 2007, January 2010, December 2014, and December 2018.

Numerous studies have documented the lethal effects of acute heatwaves on trees (Yi et al. 2022, Breshears et al. 2021 and references therein). This includes synergistic effects of combined heat and drought. Extreme heat can cause photo-system damage and reduced photosynthetic capacity, over and above hydraulic failure and tissue desiccation caused by drought. Heat and drought can also cause chronic, sub-lethal damage to trees rendering them vulnerable to future stressors.

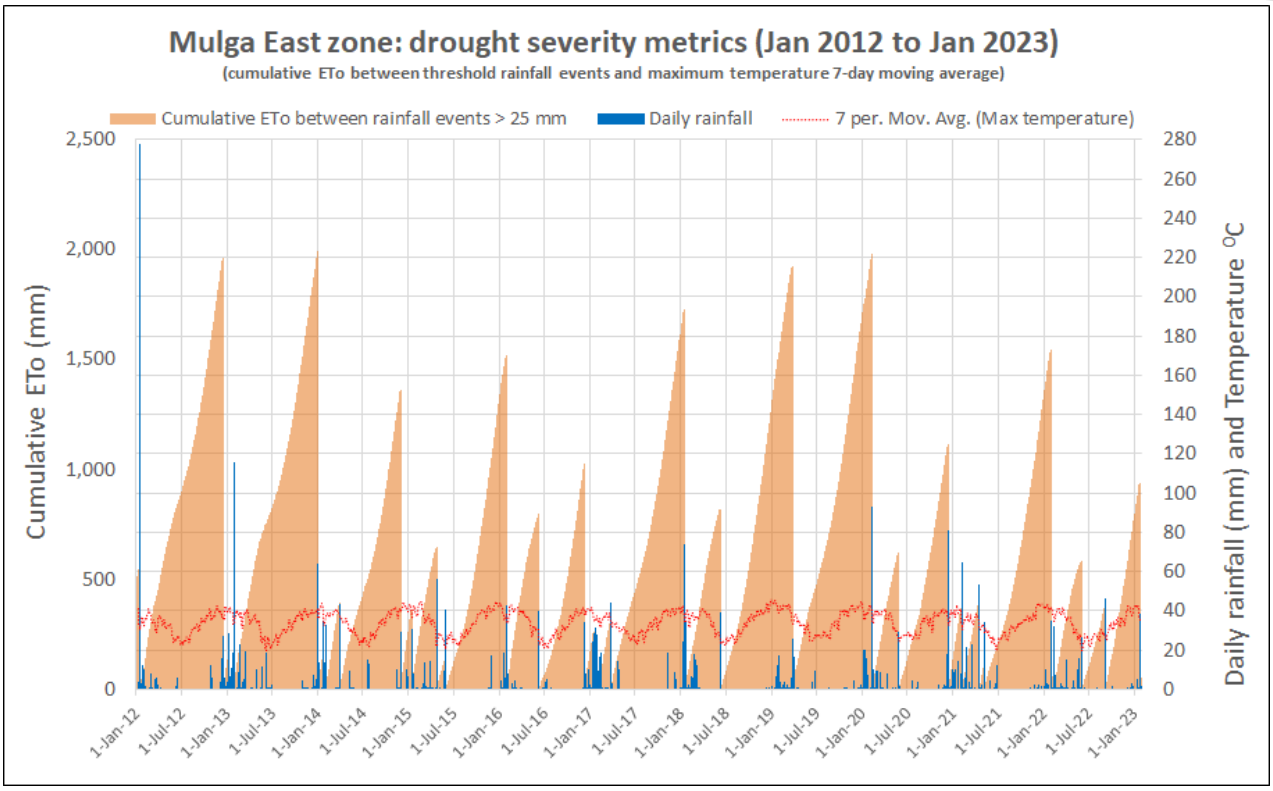


Figure 2.3 Recent Climate Trends in the Study Area

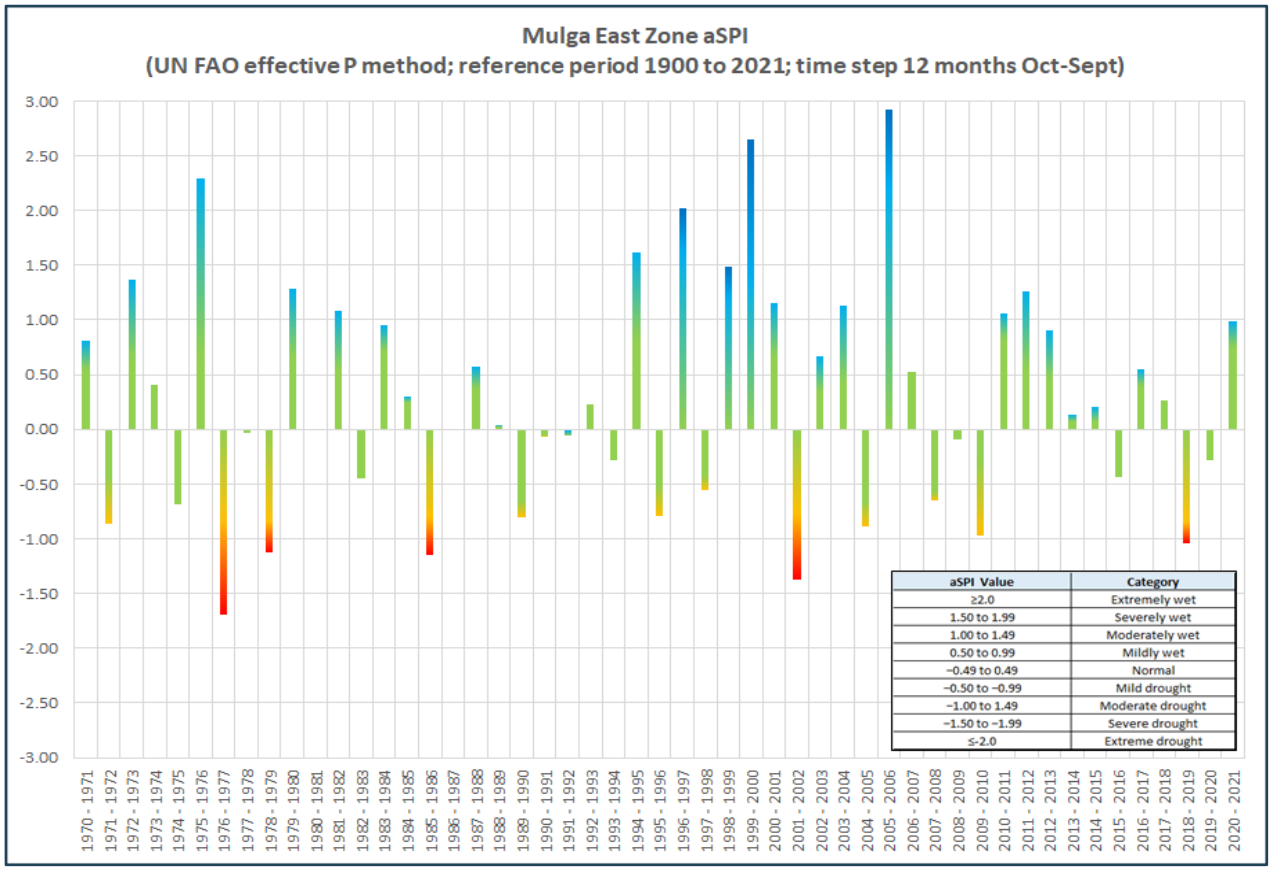


Figure 2.4 Drought Severity in the Study Area since 1970

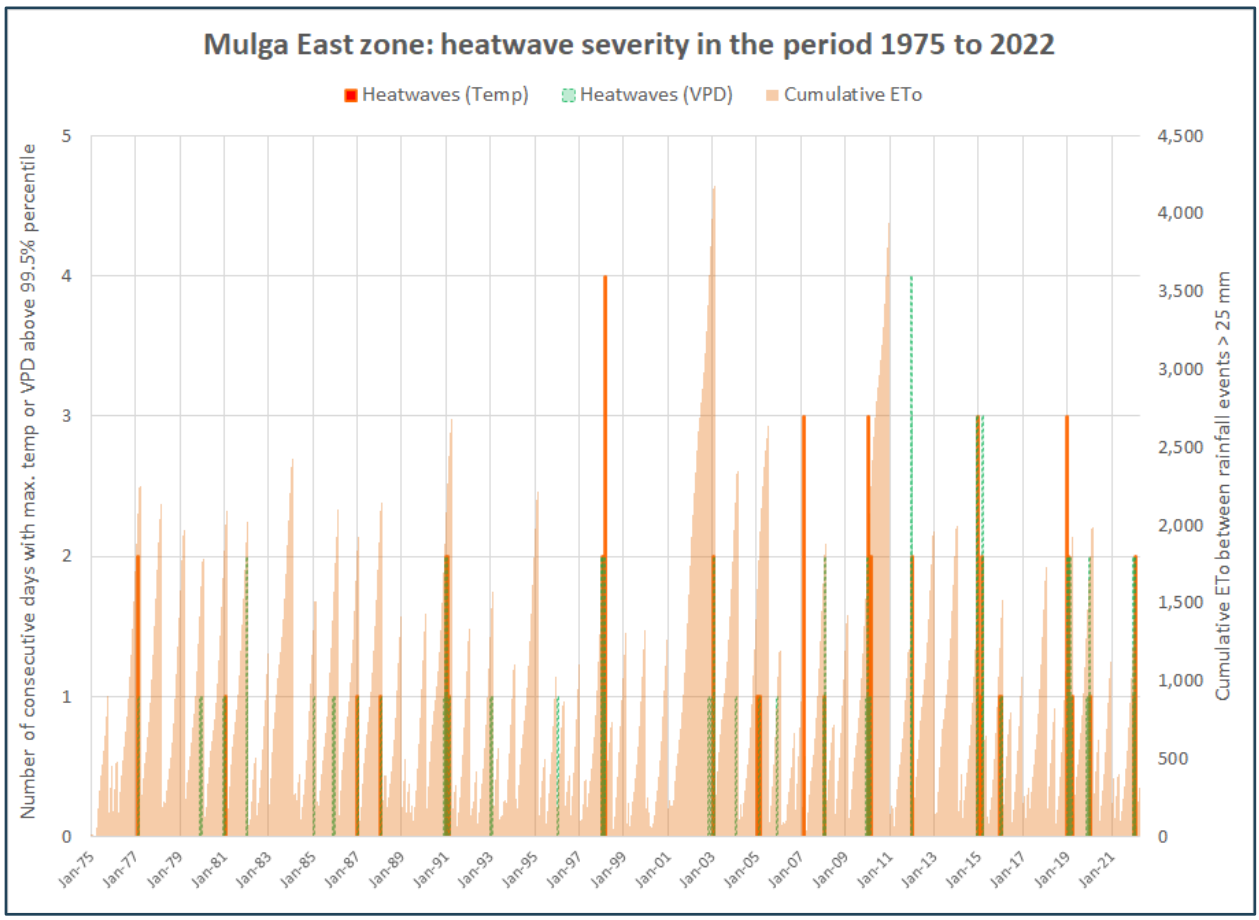


Figure 2.5 Heatwave Severity in the Study Area since 1975

2.4 Climate Change

Climate change projections give the climate response to a set of greenhouse gas, aerosol and land-use scenarios that are consistent with socio-economic assumptions of how the future may evolve. These scenarios are known as the Representative Concentration Pathways (RCPs). The climate projections developed by the CSIRO, Bureau of Meteorology (BoM) and Western Australian Department of Water (DoW) show very high confidence for substantial temperature increases across various emission trajectories (RCPs) to continue in the Pilbara (DoW, 2015; Sudmeyer, 2016). The results indicate that annual average temperature is projected to increase by 0.6–1.5°C by 2030 and by 1.5–3.1°C and 3.1–5.6°C by 2090 for medium (RCP4.5) and high (RCP8.5) emission trajectories respectively. Annual rainfall projections are subject to considerable uncertainty, with the range of projections including both decreases or increases. However, by the end of the 21st century there is high confidence that natural rainfall variability will remain the primary driver of rainfall changes. There is medium confidence that tropical cyclones will become less frequent in future but will increase in intensity. These changes are likely to increase the exposure of vegetation and other biota to water stress. For some species, which are already persisting near their upper limits of climatic extremes and resource limitations, there is a risk of species decline/loss and associated ecosystem destabilisation if climate change intensifies (Lewandrowski et al. 2021).

2.5 Site Collected Data

Across the Mulga Downs region three private rain gauges were installed by HPPL, these include Mulga Downs Exploration Camp (MDEC), Drillers Ridge and Bismark Gorge. In addition, there are a number of BoM run weather stations in proximity to the Project, namely Mulga Downs (ID 5015), Wittenoom (ID 5026) and Karijini North (ID 5098). Of these BoM stations, only Karijini North remains operational. The location of these weather stations is shown in Figure 2.6.

A summary of the available data from these weather stations is summarised in Table 2.2. Note that the data from the HPPL weather station is recorded at varied intervals, most commonly in 30-minute increments but also in hourly increments. There is also a large amount of missing data and some discrepancies in the recordings. As a result of this, and distance from the Project, only the MDEC rainfall recordings have been used in the baseline assessments. Where the MDEC rainfall is missing, data from the BoM weather stations has been used to complete the data set. The order of preference for the use of data is summarised in Table 2.2.

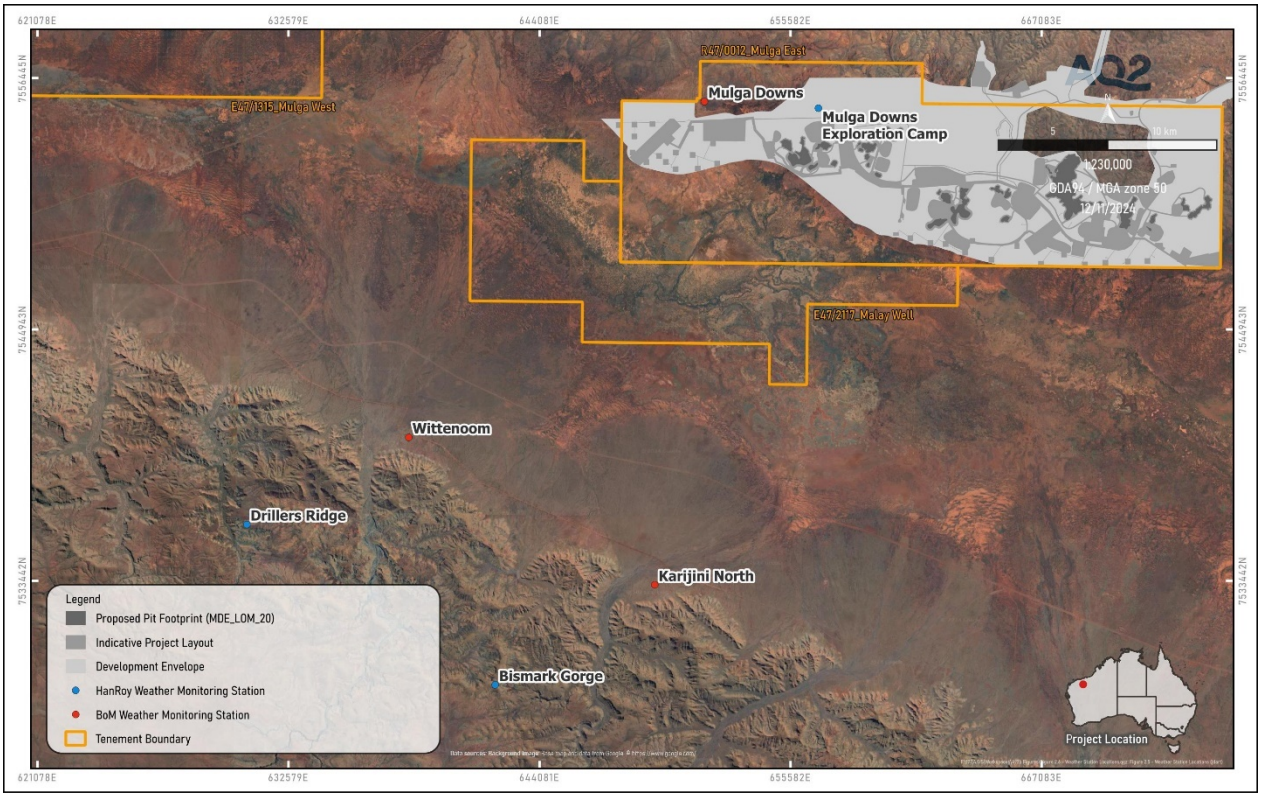


Figure 2.6 Regional Weather Station Locations

Table 2.2 Available Weather Station Data

Weather Station	Owner	Priority	Easting	Northing	Open	Close	Completeness** (%)
Mulga Downs Exploration Camp	Hanroy	1	656864	7555069	*2018	-	45%
Mulga Downs (BoM 5015)	BoM	2	651639	7555371	1897	2019	90%
Karijini North (BoM 5098)	BoM	3	649363	7533248	2018	-	95%
Wittenoom (BoM 5026)	BoM	4	638090	7539995	1949	2019	94%
Drillers Ridge	Hanroy	5	630670	7536006	*2022	-	40%
Bismark	Hanroy	6	642052	7528668	*2023	-	20%

*This corresponds to the first data point in the provided data set.
** Completeness refers to the available data between the first and last datapoint provided.

Within the data collected by the MDEC the largest rainfall event (which also shows a significant response in the monitored creeks) occurred on the 5th of January 2020, where a total of 93 mm fell over 2.5 hours (half hourly rainfall depths shown in Figure 2.7). This rainfall event was used to calibrate the hydrology model to develop estimates of rainfall losses to be used in wider flood study work (discussed further in Section 4).

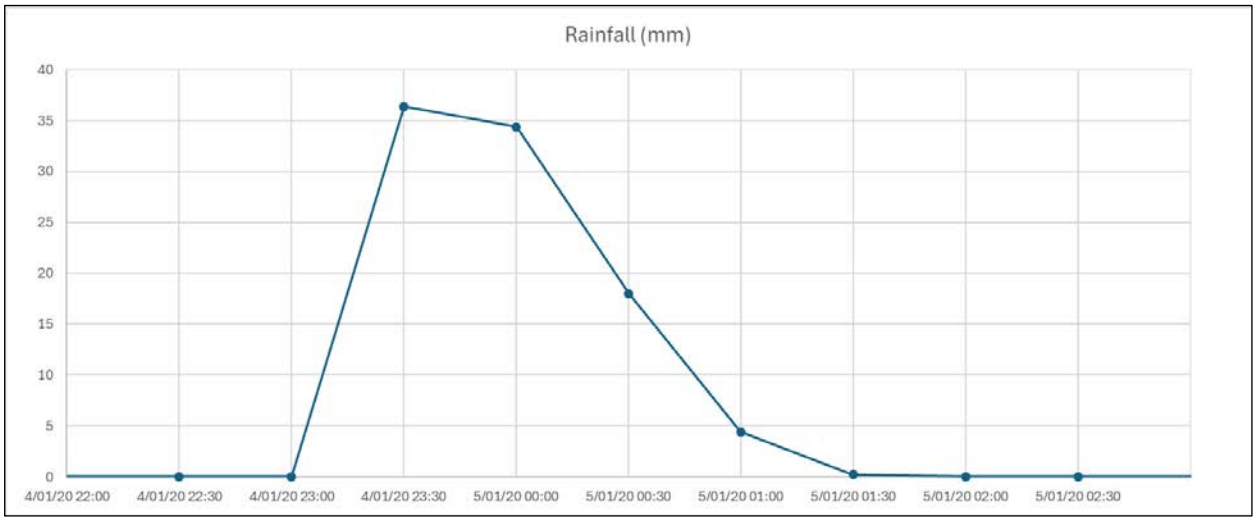


Figure 2.7 Isolated Rainfall Event from MDEC (5/1/2024)

The rainfall within the Pilbara is characterised as having a high degree of spatial variability. Figure 2.8 shows the average annual rainfall totals for three distinct periods in the climate record (as discussed in Section 2.2). The graph shows that the average rainfall recorded at Wittenoom and Mulga Downs BoM weather stations between 1953 and 1998 were relatively similar, however between 1994 and 2018, there is a significant difference in the average rainfall total between the two rain gauges (with Wittenoom being wetter). This period coincides with the wetter period of rainfall as discussed in Section 2.2.

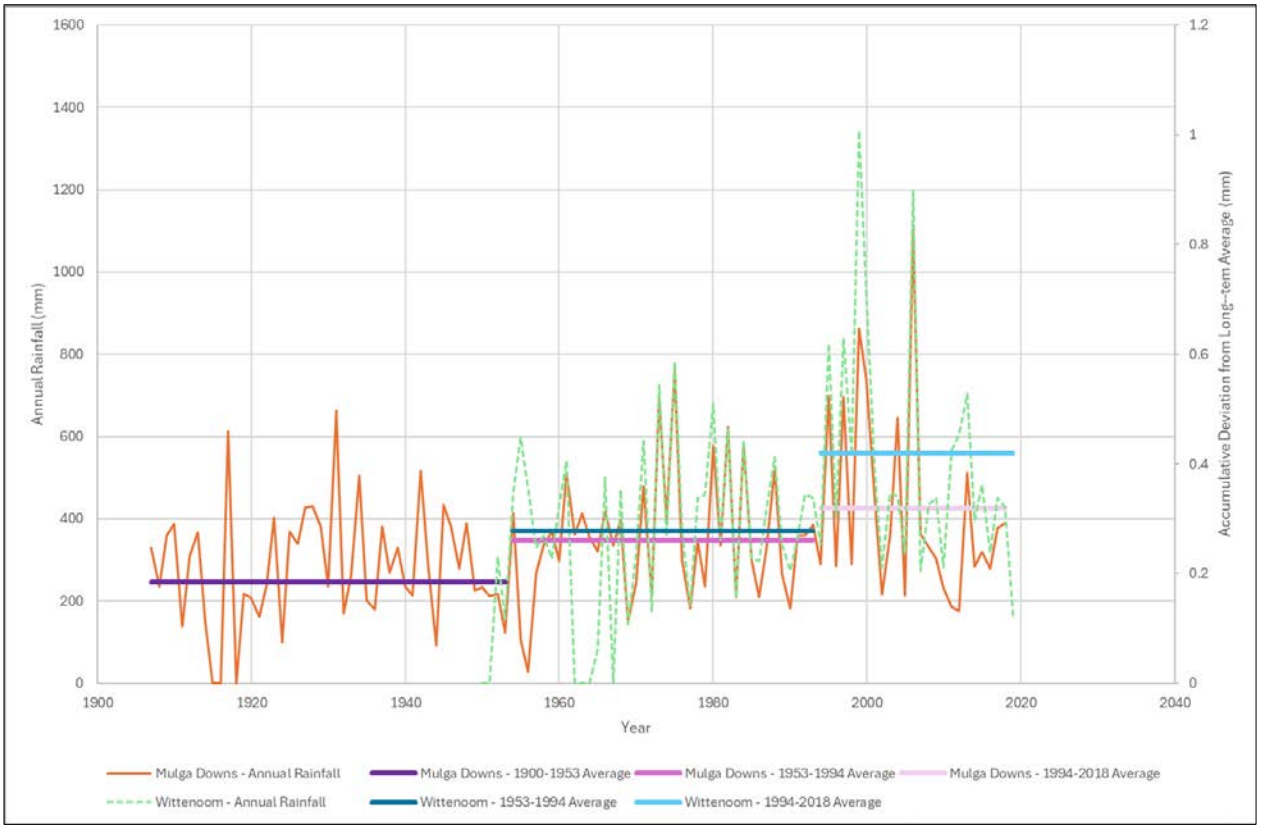


Figure 2.8 Annual Rainfall Comparison (BoM Mulga Downs and Wittenoom Weather Stations)

2.6 Compiled Rainfall Data Sets

Two sets of rainfall data have been created for use in the baseline assessments documented in this report for the following purposes:

- Data Set 1: sub-daily rainfall data, for use in determining runoff parameters for surface water modelling.
- Data Set 2: daily rainfall data, for use in groundwater assessments and claypan water balance modelling.

Data Set 1 was compiled from the HPPL weather stations to create a 30-minute interval rainfall data set. The data set spanned from 2019 to 2023, and used MDEC rainfall where it was available, and Drillers Ridge and Bismark Gorge data to patch missing periods from MDEC. Note that despite having data from all three weather stations, Data Set 1 only covered 49% of the period between 2019 and 2023.

Data Set 2 used the MDEC 30-minute rainfall records (summed to a daily total) for the recent rainfall and the BoM Mulga Downs rainfall station for longer-term rainfall data. Gaps in the record were patched using data from BoM's Wittenoom and Karijini rainfall gauge as per the priorities shown in Table 2.2. A plot of the daily rainfall records is provided in Figure 2.9. Within the data set, 4 daily rainfall events significantly exceeding 150 mm rainfall occur (noting the measurements are fixed 24-hour periods and not a sliding 24-hour duration, such that larger events are likely to have occurred spanning successive records). Daily rainfall events of 324 mm, 167 mm, 207 mm and 189 mm were recorded in 1975, 1997, 1999 and 2003 respectively. Different periods of this data have been sampled depending on the application (as outlined in the following sections).

Note that since baseline surface water data has been collected from the site (October 2018), there has not been a significant daily rainfall event (over 100mm), compared to the long-term record. Note the red line on the figure represents the date that baseline surface water monitoring commenced.

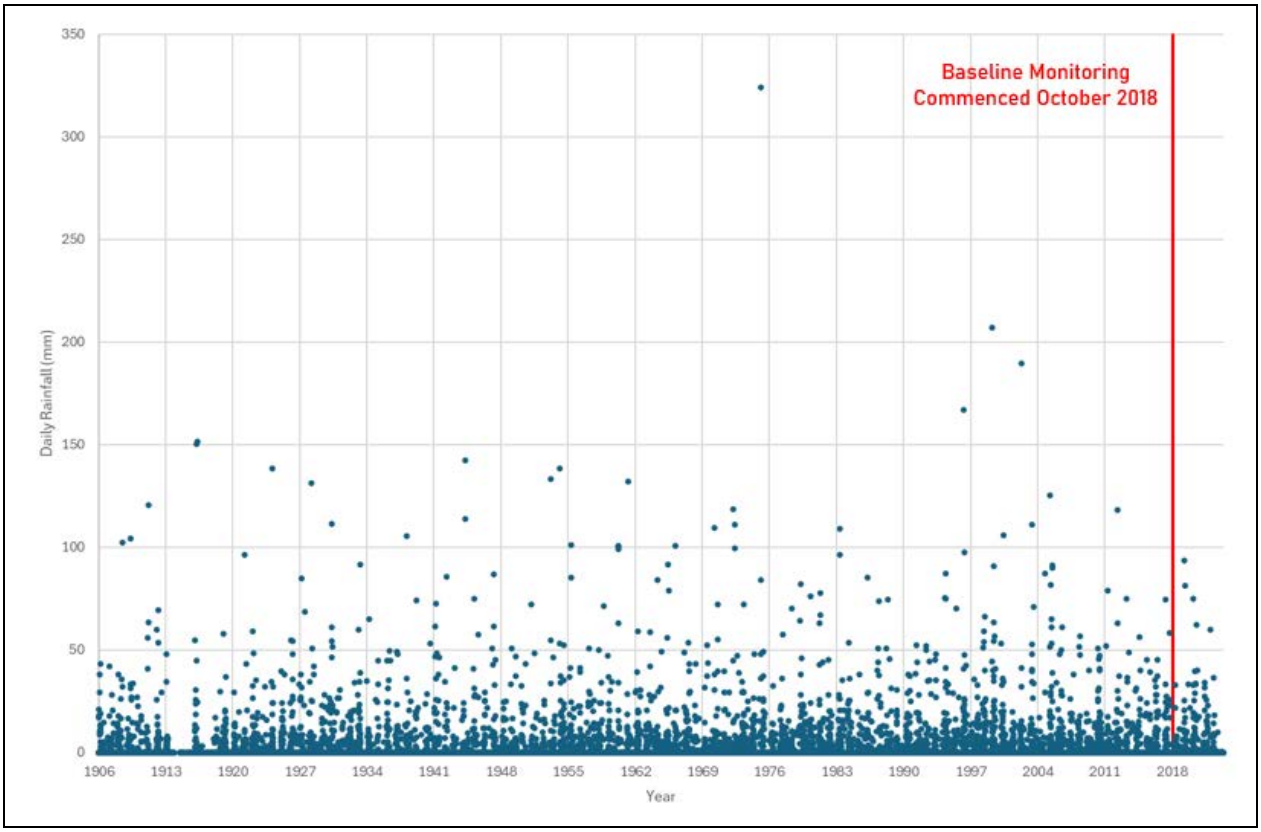


Figure 2.9 Mulga Downs Collated Daily Rainfall

2.7 Intensity Frequency Duration Data

Intensity-Frequency-Duration (IFD) data was extracted from the BoM website for the Project from the 2016 datasets. The 2016 IFD data is presented in Figure 2.10.

Australian Rainfall and Runoff (ARR) (Ball, et. Al, 2019) recommends the use of Annual Exceedance Probability (AEP) when defining flood probability, so this terminology has generally been adopted throughout this report. AEP is defined as the probability or likelihood of an event occurring or being exceeded within any given year, usually expressed as a percentage. This new terminology supersedes the Annual Recurrence Interval (ARI) terminology adopted in the earlier revision of ARR (Institution of Engineers, Australia, 1987). The relationship between ARI and AEP is defined below.

$$AEP = 1 - \exp(\frac{-1}{ARI})$$

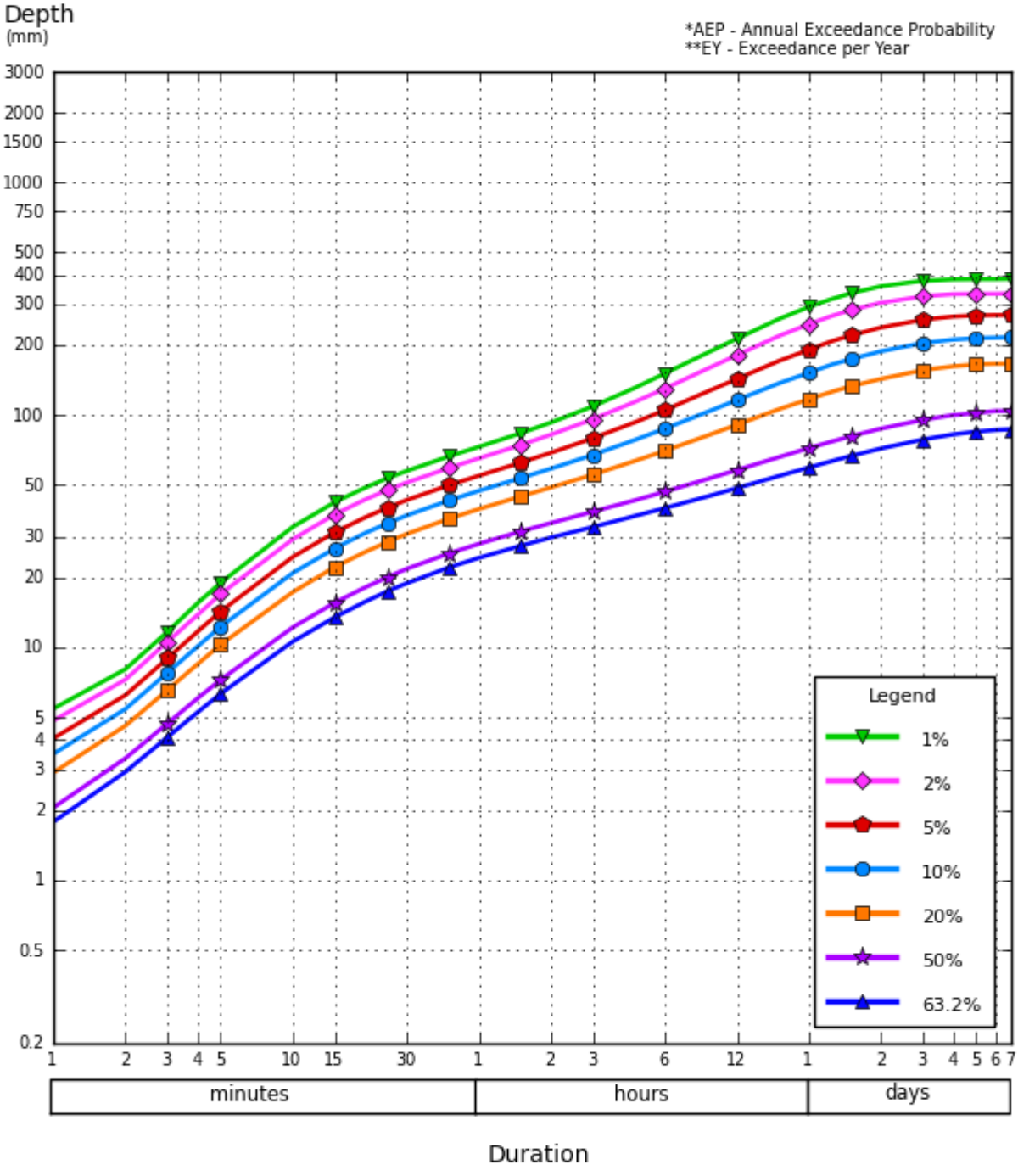
For example, a 1 in 100 ARI event would occur on average once every 100 years and has a 1% chance of occurring in any particular year (i.e. 1% AEP), while a 1 in 50 ARI event has a 2% chance of occurring (2% AEP).

Requested coordinate Latitude: -22.0875 Longitude: 118.4625
Nearest grid cell Latitude: 22.0875 (S) Longitude: 118.4625 (E)

IFD Design Rainfall Depth (mm)

Issued: 25 May 2022

Rainfall depth in millimetres for Durations, Exceedance per Year (EY), and Annual Exceedance Probabilities (AEP).



©Copyright Commonwealth of Australia 2016, Bureau of Meteorology (ABN 92 637 533 532)

Figure 2.10 BoM IFD Design Rainfall Depths (BoM, 2016)

2.8 Evaporation

Average monthly and annual pan evaporation values were obtained from BoM and the Department of Agriculture (Luke et al., 2003) and are presented in Table 2.3. The BoM pan evaporation rates were measured at the Wittenoom weather station and Department of Agriculture values are based on Class A pan evaporation rates collected at Tom Price. Department of Agriculture also report evaporation losses from small dams (using a pan factor of 65%), which provides an indication of the actual evaporation rates from a shallow water body in the region.

Table 2.3 Potential Evaporation

(mm)	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Annual
Wittenoom Mean Evaporation (BoM)	149	189	258	344	372	384	350	274	279	231	177	135	3,143
Tom Price Class A Pan Evaporation (Department of Agriculture)	177	189	274	371	408	460	423	320	318	263	189	169	3562
Tom Prive Dam Evaporation (65%) (Department of Agriculture)	115	123	178	241	265	299	275	208	207	171	123	110	2,315

3. SURFACE WATER FIELD INVESTIGATIONS AND DATA COLLECTED

Site investigations to collect baseline surface water data have been conducted across the Study Area and are continuing. These investigations have included monitoring of the water levels within creeks reporting to the Study Area, monitoring water levels of ponded water within claypans and water quality sampling of creek flows and ponded water in the claypans

3.1 Surface Water Monitoring Stations (Existing)

As part of the baseline hydrological study, eight surface water monitoring locations (SWML) have been established, with six sited on claypan tributaries and two in the claypans (one in each of the Gnalka Gnoona and Koodjeepindarranna Claypans). The six selected tributaries are all located on the northern (Chichester Range) side of the claypans as the HPPL tenements do not cover defined tributaries coming from the south (Hamersley Range) side of the claypans.

Each of the six creek monitoring locations consists of the following:

- Pressure transducer, EC sensor and associated data logger to measure and record water pressure (which is converted to a water depth) and EC.
- Passive sample collection bottle housed within a mounting kit to collect water quality samples after medium to large runoff events.

Each of the two claypan monitoring locations only consists of a pressure transducer, EC sensor and associated data logger (no passive sample collection devices). Instead, the Koodjeepindarranna and Gnalka Gnoona claypans are sampled by 2 transects, with the sample taken at the water's edge where it intersects the transect.

Installation information for each monitoring location, and the associated upstream catchment areas reporting to each monitoring location are provided in Table 3.1 and Table 3.2 for the creeks and claypans, respectively. The maximum potential catchment areas draining to each monitoring location are also shown on Figure 3.1 and Figure 3.2. It should be noted that the catchment areas draining to the claypan monitoring locations are difficult to define given the relative shallow slopes within the Fortescue Valley, the complex behaviour of runoff from incised drainage channels within the ranges once the runoff reaches the alluvial fans and the lack of defined drainage channels (hence a maximum potential catchment area for each claypan has been defined). The results of the baseline 2D hydraulic flood modelling exercise (presented in Section 4.3) were used to assist in refining the effective catchment areas adopted for the claypans. These refined catchment areas are smaller than those reported in Figure 3.2 and are discussed further in Section 4.3.

Table 3.1 Creek Surface Water Monitoring Stations

Logger Serial Number	Location ID	Installation Date	Feature Type	Coordinates (UTM Zone 50)	Record Interval (Minutes)	Catchment Area Estimate* (km^2)
018-1075259	SWML01-A	10/10/18 **	Creek reporting to Koodjeepindarranna Claypan	651241 E, 7556082 S	15	127.5
018-1075259	SWML01	28/07/20	Creek reporting to Koodjeepindarranna Claypan	651075 E, 7555241 S	15	134.6***
018-1075264	SWML02	12/10/18	Creek reporting to Fortescue Valley immediately upstream of Gnalka Gnoona Claypan	667963 E, 7550632 S	15	32.8
018-1075992	SWML05	11/10/18 (06/05/2020)#	Creek reporting to Gnalka Gnoona Claypan	656713 E, 7555960 S	15	6

Logger Serial Number	Location ID	Installation Date	Feature Type	Coordinates (UTM Zone 50)	Record Interval (Minutes)	Catchment Area Estimate* (km^2)
1009302	SWML06	9/05/23	Creek reporting to Fortescue Valley upstream of Gnalka Gnoona Claypan	664587 E, 7553273 S	30	20.9
971457	SWML07	16/11/23	Creek reporting to Fortescue Valley upstream of Gnalka Gnoona Claypan	668999 E, 7554721 S	15	24.5
973240	SWML08	16/11/23	Creek reporting to Fortescue Valley upstream of Gnalka Gnoona Claypan	671812 E, 7551062 S	15	0.8

* Estimated catchment areas delineated using detailed DEM data provided by HPPL. Effective catchment areas may change with the size of the rainfall event.

** SWML01-A replaced by SWML01 in a downstream location.

*** Drainage breakout likely to occur across multiple drainage paths across the alluvial fan. Logger is installed in the main drainage channel through the alluvial fan but may not detect all flow from the upstream catchment area.

Initial SWML05 was damaged and a new one reinstalled at the same location.

Table 3.2 Claypan Surface Water Monitoring Stations

Logger Serial Number	Location ID	Installation Date	Feature Type	Coordinates (UTM Zone 50)	Record Interval (Minutes)	Potential Maximum Catchment Area* (km^2)
018-1075986	SWML03	11/10/18	Koodjeepindarranna Claypan	646369 E, 7550913 S	30	1857**
018-1075250	SWML04	11/10/18	Gnalka Gnoona Claypan	651771 E, 7548466 S	30	

* Estimated maximum catchment areas delineated using detailed DEM data provided by HPPL and SRTM data. Effective catchment areas are likely to change with the size of the rainfall event and preferential flow directions at the alluvial fans. Effective catchment areas adopted in modelling are discussed in Section 4.4.1.

** Maximum potential combined catchment area of the claypans as shown in Figure 3.2; however it is likely the effective catchment area is much smaller. The red flow arrows on Figure 3.2 indicate likely flow directions that report downstream of the claypans.

The initial monitoring installation at SWML05 was destroyed (and logger recovered), most likely after a large rain event in early January 2020. A new monitoring station, with a modified design, was installed at this location on 06/05/2020. In addition, SWML01 was relocated on 28/07/2020, approximately 650 m downstream from the initial location, in the same creek channel.

Solinst Levelogger Edge 3001 pressure transducers were initially installed at each location, with each logger having the capability to monitor water level, temperature and electrical conductivity (EC). Loggers in all locations have now been replaced with In-Situ AquaTROLL (measures EC and level) transducers, due to reliability issues with Solinst Loggers.

Ongoing monitoring comprises the collection of surface water samples following rainfall events (where accessible) and periodic downloading of the loggers during groundwater monitoring rounds.

The monitoring stations were installed in two phases with SWML 1 to 5 installed in 2018 (Phase 1), and SWML 6 to 8 installed in 2023 (Phase 2). Note that data recorded from monitoring locations installed in Phase 2 are not included in this current baseline report because no runoff events had occurred between the installation date (November 2023) and the end of the period reported in this document (December 2023). Additionally, water quality samples collected along the claypan transects have only began during

2024 and are not reported in this study. Previously, water quality samples collected in the claypans (SWML03 and SWML04) were taken in proximity to the location of the SWMLs, however these locations are often inaccessible during surface water sampling runs due to the ponding in the claypans.

Water quality samples have been collected from persistent ponding in channel pools across the site (when ponding is present). The approximate coordinates of the grab sample locations are shown in Table 3.3 and these represent locations where on-going water quality samples will be collected.

Table 3.3 Channel Pool Surface Water Sampling Locations

Sample ID	Feature Type	Coordinates (UTM Zone 50)
SWML09	Channel Pool	643979 E, 7553027 S
SWML13	Channel Pool	653291 E, 7550386 S

Opportunistic samples have been taken at two further locations where ponded surface water has been observed during site visits. These opportunistic sample locations are shown in Figure 3.3 with water quality results included in the water quality sample tables shown in Appendix G. It is not proposed that these locations be sampled on an on-going basis.

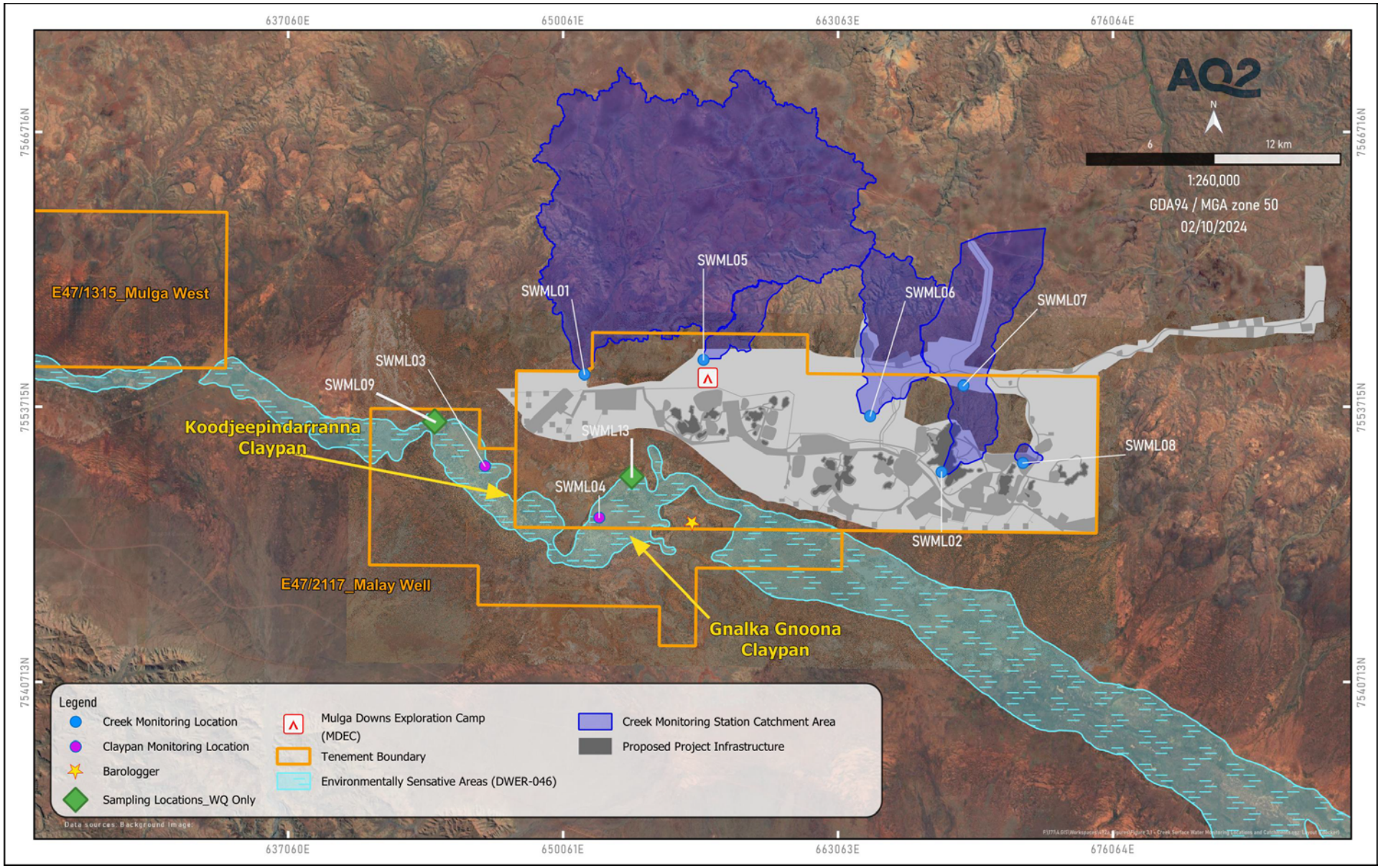


Figure 3.1 Existing Creek Surface Water Monitoring Locations and Catchments

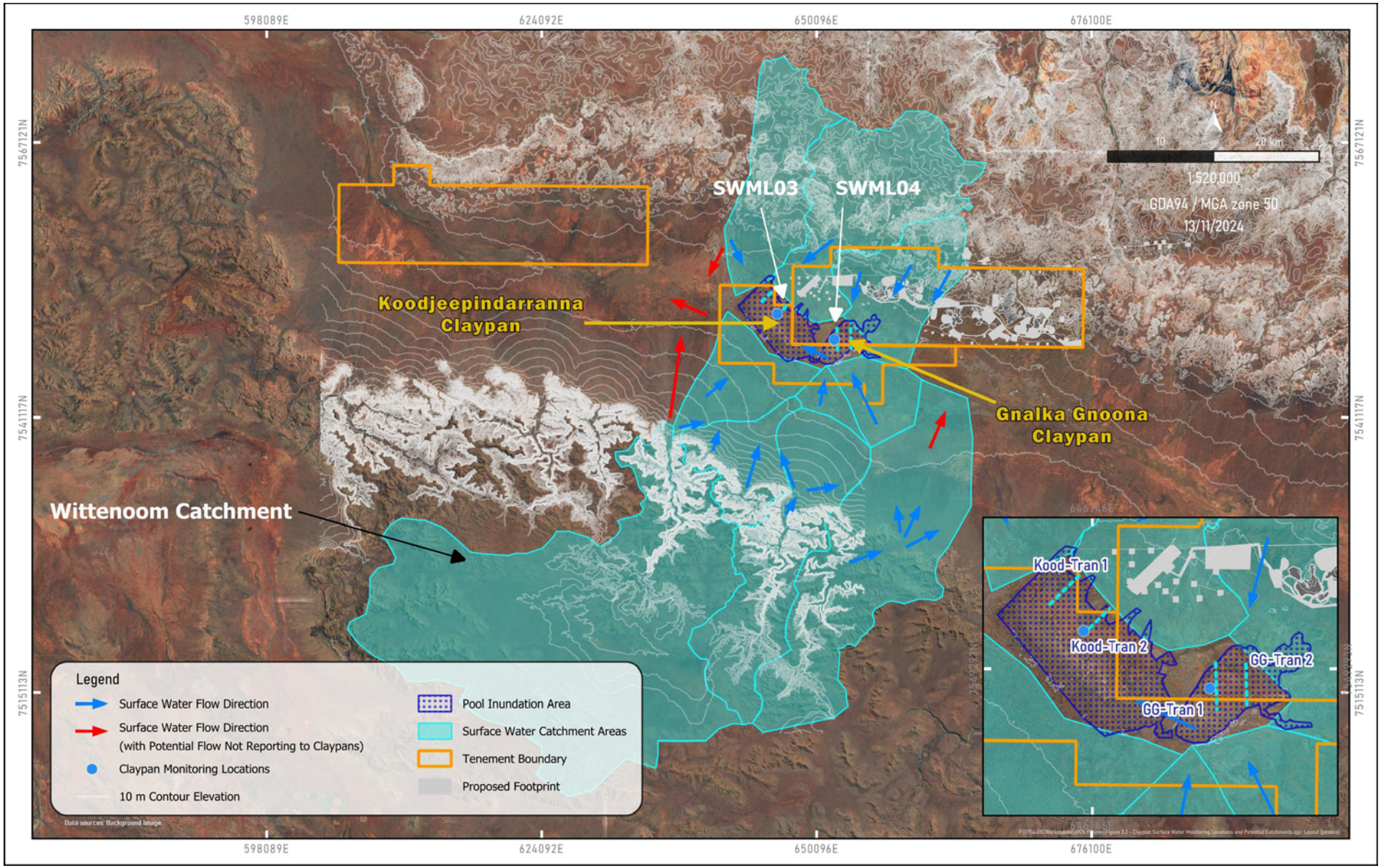


Figure 3.2 Existing Claypan Surface Water Monitoring Locations and Potential Catchments

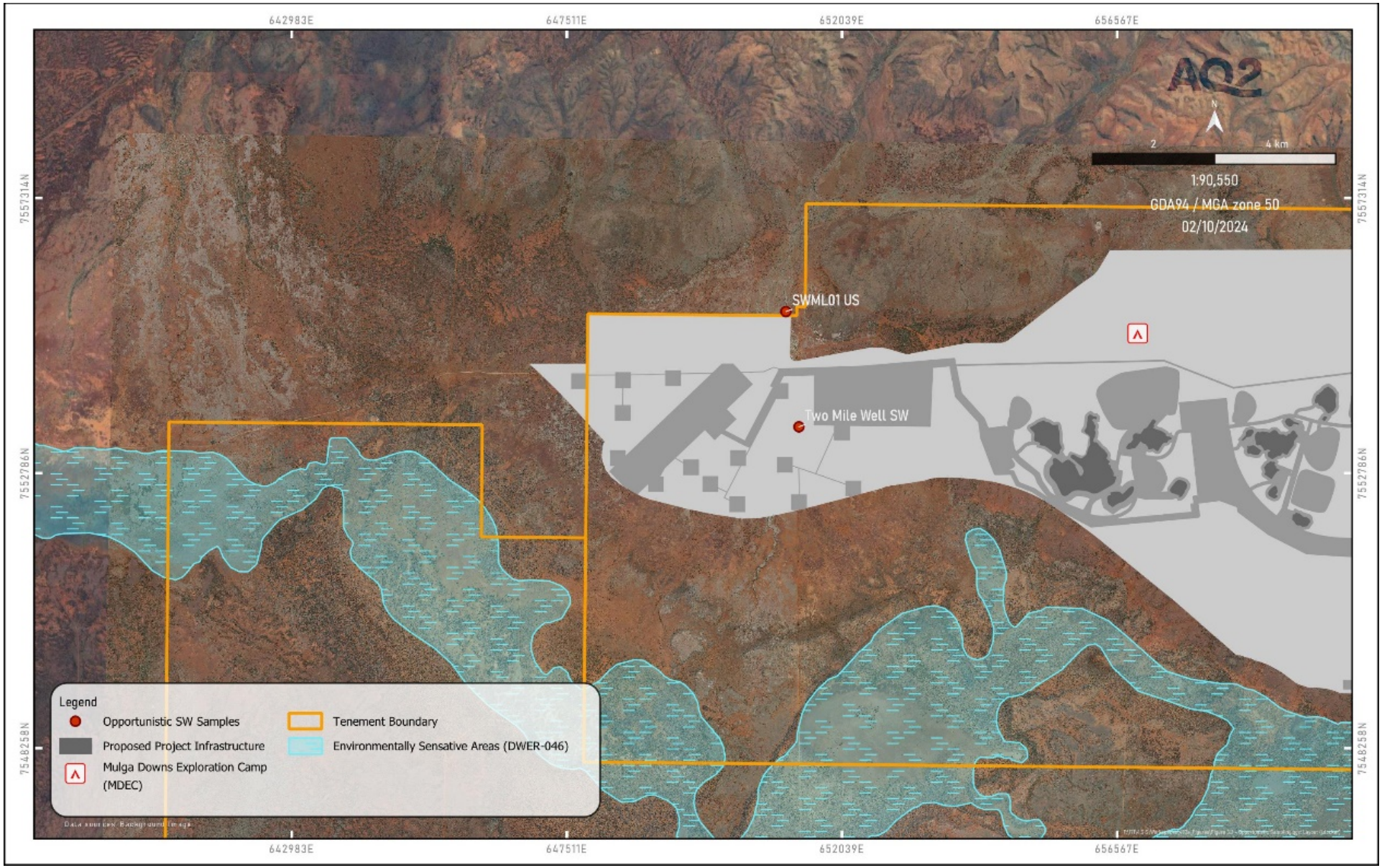


Figure 3.3 Opportunistic Surface Water Sampling Locations

3.2 Ongoing Baseline Monitoring Stations

Additional sites are proposed to be added to the Baseline Monitoring network to increase the spatial distribution of the data collected within the baseline water level and water quality data set. The additional sites are proposed due to:

- The requirement for an increased understanding of the site hydrological conceptual model and environmental assets.
- Updates to the mine development plan which allows consideration of operational monitoring requirements.
- The requirement to provide some robustness for critical monitoring sites by providing multiple reference sites.

The following additional monitoring locations have been proposed to be installed (for both water level and quality) as part of ongoing baseline monitoring but are waiting on heritage approval before they can be installed/sampled:

- At the low point within each of the claypans to provide a backup monitoring location for claypan water levels in the event of a logger failure.
- At two select channel pool location; one upstream of the claypans and one to the north of Gnalka Gnoona Claypan.

Note while there are two existing monitoring locations in the claypans, there were discrepancies identified during data analysis regarding actual elevations. Additional stations will allow for redundancy and likely lead to more reliable results.

Additional locations have been proposed to obtain regular water samples (no logger proposed) where the development has the potential to impact water quality:

- Channel connecting the claypans.
- Channel pool to the northwest of Koodjeepindarranna Claypan.
- Channel pool on the valley floor upstream of the claypans to which runoff from the eastern mining area reports. This location is outside of the mine tenement area.

The locations for these proposed monitoring stations are shown in Figure 3.4, which provides a map of the full baseline monitoring network. Access to the baseline monitoring network is subject to heritage approvals.

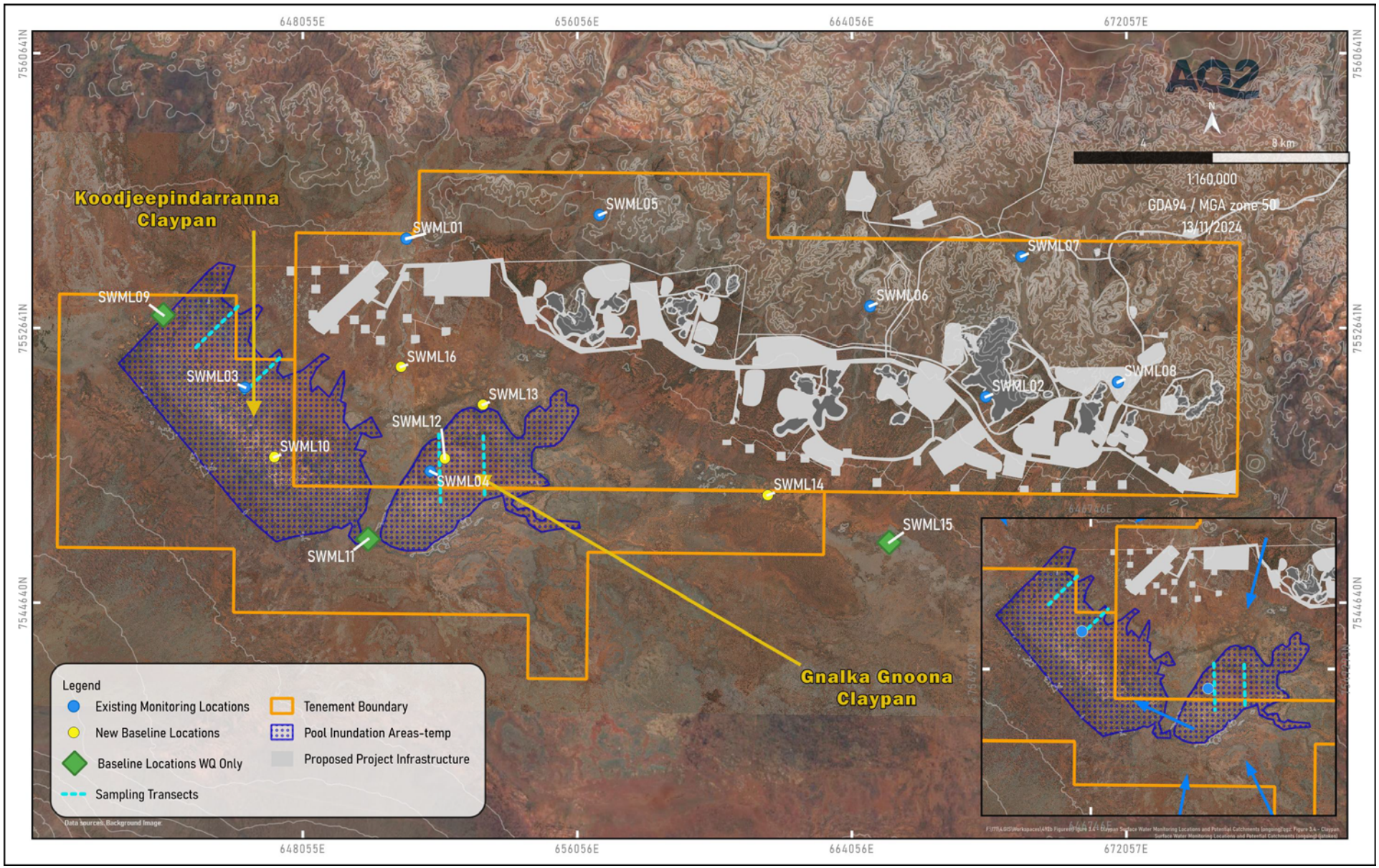


Figure 3.4 Ongoing Claypan Surface Water Monitoring Locations

3.3 Water Quality Data

Surface water samples were collected between 2020 and 2023, both within creek lines, claypans, and channel pools for laboratory analysis. The existing baseline monitoring network is shown in Figure 3.1.

The following number of water quality samples have been collected:

- SWML01 – 5 samples.
- SWML02 – 4 samples.
- SWML03 – 4 samples.
- SWML04 – 5 samples.
- SWML05 – 3 samples.
- SWML09 – 1 sample.
- SWML13 – 1 sample.

Surface water samples have generally been tested for the following parameters:

- General water quality (pH, Conductivity, Na, K, Ca, Mg, S, Si, Hardness, Alkalinity, Sulfate, Chloride, Fluoride, Silica, Nitrate, Nitrite).
- General metals suite (Ag, Al, As, B, Be, Ba, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Se, Sn, Sr, Ti, Tl, V, Zn).
- Nutrients (Nitrate, Ammonia, FRP as PO4)).
- TDS/TSS.

The water quality data and a discussion of the results is provided in Section 4.5.

4. SURFACE WATER DATA ASSESSMENT

4.1 Approach

The baseline data collected for the Study Area has been analysed to assist with determining the baseline hydrological conditions. It was identified that the hydrological behaviour of flooding within the Study Area is driven by two different mechanisms:

1. Short-duration high runoff rates in response to individual rainfall events across the Chichester Range catchments.
2. Ponding of water within the Fortescue Valley, including within the claypans (Gnalka Gnoona and Koodjeepindarranna), from either a single large or potentially from multiple successive runoff events.

The baseline hydrological conditions of the Study Area have been characterised using 2D flood modelling of catchment runoff (flood mechanism 1) and a water balance model for the claypans (flood mechanism 2). Parameters used within the surface water assessments were guided by analysis of data collected at the site during baseline field studies. Outputs from the 2D flood model were also used to quantify parameters in the water balance model of the claypans.

To model the two flood mechanisms that drive the baseline hydrological behaviour of flooding within the Study Area, a Light Detection and Ranging (LiDAR) Digital Elevation Model (DEM) representing the existing topography (pre-development) was required to simulate rainfall-runoff-storage processes and stage-storage-area relationships for Gnalka Gnoona and Koodjeepindarranna claypans.

Note that the assessments described below have predominantly used the most recent (2023) 0.25 x 0.25 m and 0.5 x 0.5 m LiDAR data sets which cover an extensive region around the Project location, extending across the Fortescue Valley to the base of the Hamersley Range. For some of the modelling and catchment definitions, the 2019 LiDAR DEM (less extensive coverage compared to 2023) and freely available SRTM data was used.

An overview of the 2023 LiDAR data is shown in Figure 4.1.

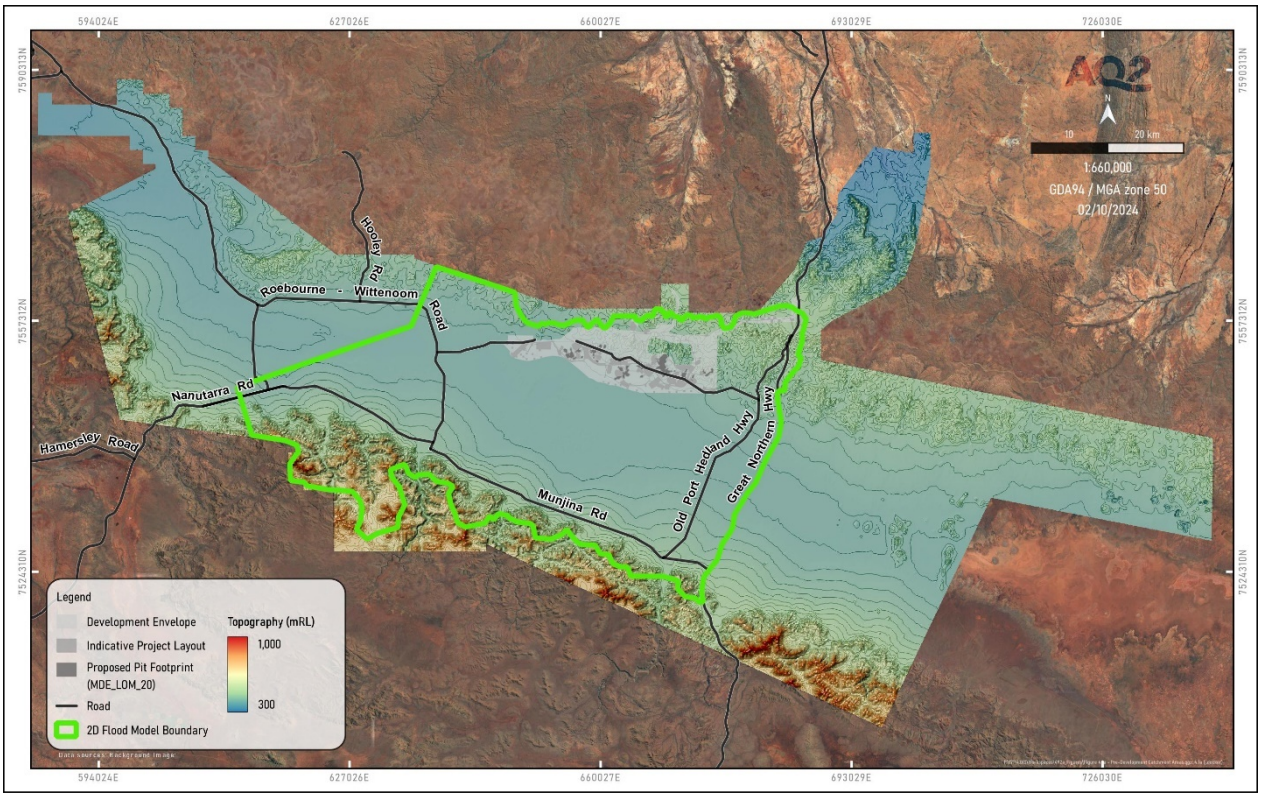


Figure 4.1 Supplied LiDAR Data

4.1.1 Baseline 2D Flood Modelling

The baseline 2D flood modelling was completed for a range of design rainfall events, ranging from 63% to 1% Annual Exceedance Probability (AEP), to simulate surface water flows within the Study Area and Fortescue Valley. The maximum flood depths and velocities predicted by the 2D flood model for baseline (pre-development) conditions are included in Appendix A.

The 2D flood model was developed using the 2023 0.5x0.5 m LiDAR DEM which included detailed terrain for the Study Area, the Chichester Range, and the Fortescue Valley between the Great Northern Highway and downstream of the Fortescue railway (to the west). A comparison of the model boundary to the LiDAR DEM extents are shown in Figure 4.1. The LiDAR DEM resolution and extent was considered appropriate to assess the hydrological behaviour of flooding within the Study Area. The results of the 2D flood model were subsequently used to:

- Assist in defining catchment boundaries (such as for the claypans, broader Goodiadarrie Swamp area and surface water monitoring sites).
- Assist in developing the Conceptual Landscape Model.
- Produce baseline flood maps to be used as a reference to quantify the impact of the mine disturbance areas and any required flood protection measures on the hydrological environment.
- Identify potential environmental impacts of mine infrastructure as a result of changes to the existing surface water regime (as part of the impact assessment report (AQ2 2024)).
- Identify where flood protection measures are required around the mine disturbance areas (pits, waste rock dumps etc.) as part of the Environmental Impact Assessment Report.

4.1.2 Claypan Water Balance

The water balance model of the Gnalka Gnoona and Koodjeepindarranna Claypans was completed to:

- Define the claypans' baseline hydrological regime.
- Predict potential flood levels that may occur due to water storage within the claypans.
- Develop a baseline dataset on surface water quality based on collected water quality data during the pre-mining period.
- Assist in developing the Conceptual Landscape Model.

4.2 Mine Development Catchment Definition

The baseline surface water catchments relative to the proposed mine development area have been delineated to the Fortescue Valley Environmentally Sensitive Area (ESA) as defined by DWER. The following datasets have been used to delineate the baseline catchment areas:

- 2023 LiDAR DEM.
- SRTM datasets.
- Aerial imagery.
- Initial flood model results.

Baseline catchment areas are presented in Figure 4.2, with the size of each catchment area summarised in Table 4.1.

Table 4.1 Mine Development Area Baseline Catchment Area Summary

Catchment	Baseline Area (km^2)
1	23.1
2	164.4
3	39.8
4	28.4
5	33.8
6	13.5
7	29.0
8	11.9
9	43.3
10	53.9
11	65.5
12	1.7
13	6.3
14	2.1
15	4.5
16	7.3

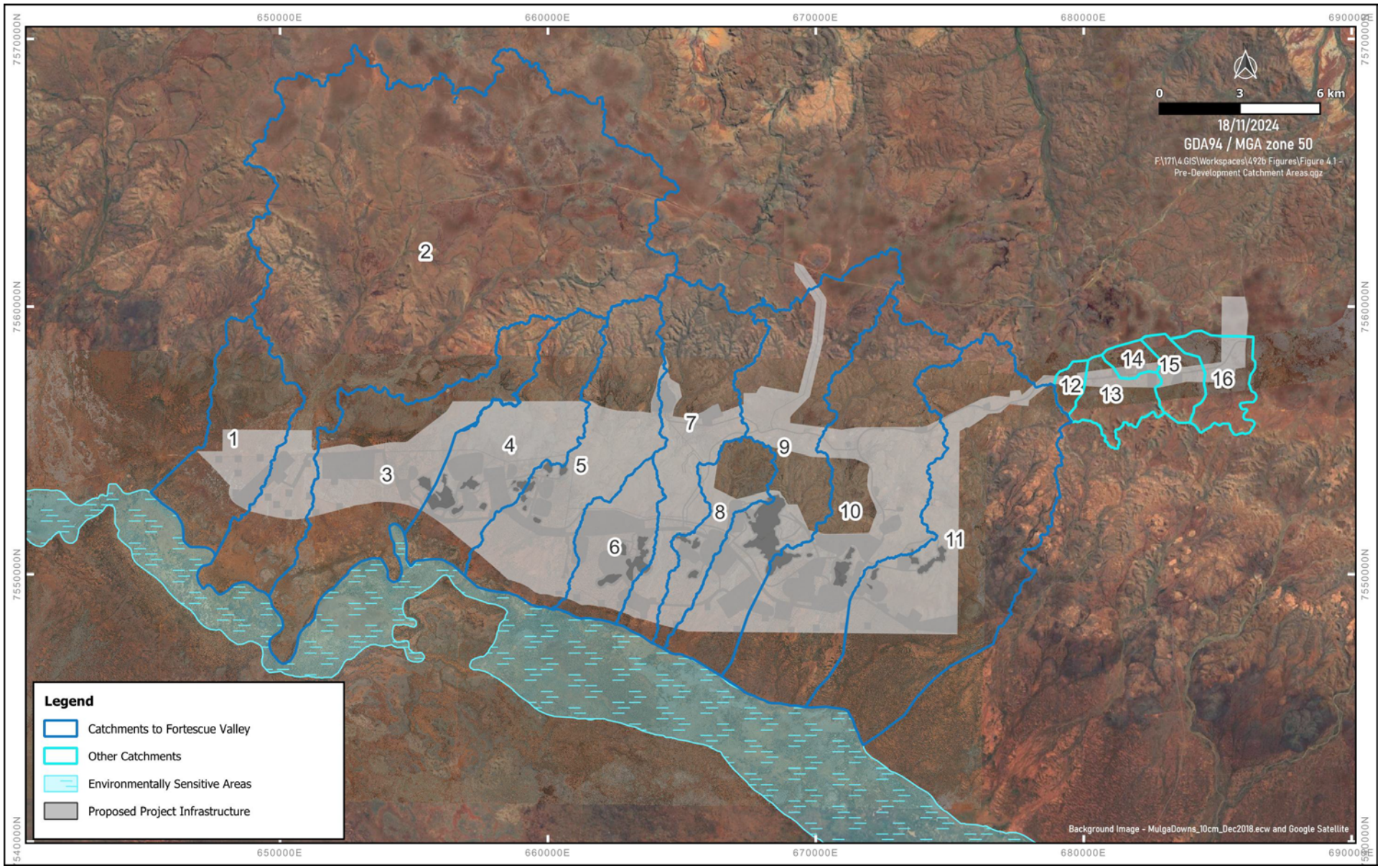


Figure 4.2 Pre-Development Catchment Areas

4.3 Baseline Flood Modelling

The baseline flood characteristics of the Study Area have been mapped by creating a 2D flood model using the Hydrologic Engineering Center's (CEIWR-HEC) River Analysis System (HEC-RAS). The following steps were taken when developing the 2D flood model:

- Analysis of baseline streamflow data collected from monitoring stations to assist in defining catchment rainfall loss parameters.
- Definition of catchment areas reporting to the boundary of the 2D flood model.
- Development of runoff-routing models using RORB (Laurenson et al.,2010) to define inflow hydrographs along the 2D model boundary for the 63%, 50%, 20%, 10%, 5% and 1% AEP runoff events.
- Development of the 2D flood model for the 63%, 50%, 20%, 10%, 5% and 1% AEP runoff events using upstream inflow hydrographs plus rain-on-grid runoff hydrology.
- Mapping of maximum flood depths across the model domain for the design runoff events.
- Mapping of maximum flow velocity across the model domain for select runoff events.

These steps are outlined in the sections below.

4.3.1 Stream Flow Data Analysis

As discussed in Section 3.1, six Surface Water Monitoring Locations (SWML01, SWML02, SWML05, SWML06, SWML07 and SWML08) have been installed in proximity to the Project within drainage lines from the Chichester Range. All of the collected creek data is shown in Appendix B, noting that to date, no baseline data has been collected from SWML06, SWML07 or SWML08.

Data collected during the baseline monitoring phase was reviewed and the following was completed:

- Pressure transducer measurements were converted to a calculated water depth accounting for recorded barometric pressure readings.
- The water depths were converted to a relative level using the surveyed elevation of the monitoring station locations (taking into account dimensions of housing and cable lengths).
- Rating curves defining a flow rate versus flow depth relationship for each of the SWMLs were developed by preparing a localised 2D flood model of the terrain immediately upstream and downstream of the SWML. Note:
    - The 2D flood model used the 2019 LiDAR Digital Elevation Model (DEM) provided by HPPL to define the terrain underpinning the model.
    - Surveyed cross-sections were provided which were used to modify the DEM.
    - There were instances where the surveyed ground elevation at the SWML and the elevation within the DEM differed, leading to uncertainty in the water level monitoring data.
- The measured flow depth data was converted to a flow rate using the developed rating curves.

The measured flow responses were compared with gauged rainfall data from the Mulga Downs Exploration Camp (MDEC) to identify rainfall events that produced a streamflow response. The intent of this step was to identify rainfall events and the corresponding runoff events that could be used to calibrate rainfall losses within a hydrological model. The measured events were therefore filtered to remove those that were unsuitable for calibration.

There have only been a few runoff responses recorded by the SWMLs to date. Commonly across all sites, a large rainfall event in January 2020 triggered responses with a peak flow rate estimated to be almost 500 m^3/s (~3m deep flow) through SWML01 (based on the developed rating curve). The flow occurred as a result of a 24-hr 93mm event with flow only present through SWML01 for a total 26-hour period during and post the event.

A rainfall response event at SWML01a in January 2020, was selected as the only event suitable for use to calibrate the hydrological model. This runoff event was in response to the most significant rainfall event which has been recorded during the baseline period (93 mm over 2.5 hours, refer Section 2.5). The following factors limited the number of events that could be chosen:

- The majority of rainfall events that were measured at the rainfall gauge station were relatively small and therefore the creek flow responses were relatively shallow and occurred over a short-duration.
- The available rainfall records from the MDEC were predominately daily measurements containing significant gaps that could only be filled with rainfall data from the nearest operational BoM weather station, which was Karijini North (005098). Half-hourly rainfall data from the MDEC was only available for approximately half of 2020 and also contained gaps.
- The distance between the SWMLs and the MDEC rainfall gauging station. SWML01a and SWML05 are located relatively close (5.5 km and 2.5 km respectively) to the MDEC and therefore the recorded rainfall data is more likely to be representative of the rainfall that would have fallen over their upstream catchment compared to SWML02, which is located approximately 12 km from the rainfall station.
- The surface water flow regime at the SWMLs is typically characterised by streamflow through a series of braided channels across an alluvial fan. The braided channels have formed at the change in slope as the drainage lines leave the steeper Chichester Range and reach the flatter alluvial fan. Each SWML is only representative of the flow through one of the braided channels and there is inherent uncertainty regarding the manner in which the upstream catchment flow splits across the braided channels. As the braided channels also combine to form wide floodplains under higher flows, it was found that higher flow rates were required to simulate the water surface elevations (WSEs) recorded in the gauges than would be required within a contained channel.
- The streamflow gauge at SWML05 was damaged during the January 2020 runoff event and required subsequent reinstallation resulting in a data gap between January and May 2020 (a period which included the January runoff event).

4.3.2 Rainfall Loss Parameters

A RORB rainfall routing model was developed for the catchment reporting to SWML01a using the January 2020 rainfall event. RORB generates flow hydrographs by subtracting losses from rainfall to produce rainfall-excess hyetographs and routes these hydrographs through catchment storages. The rainfall losses in the model were modified until the estimated discharge rates from the observed flow depths were approximated by the RORB model. This calibration exercise produced the closest fit using an initial rainfall loss of 35 mm and a continuing loss of 5 mm/hr. A comparison of the modelled hydrograph to the gauged discharge rate is presented in Figure 4.3.

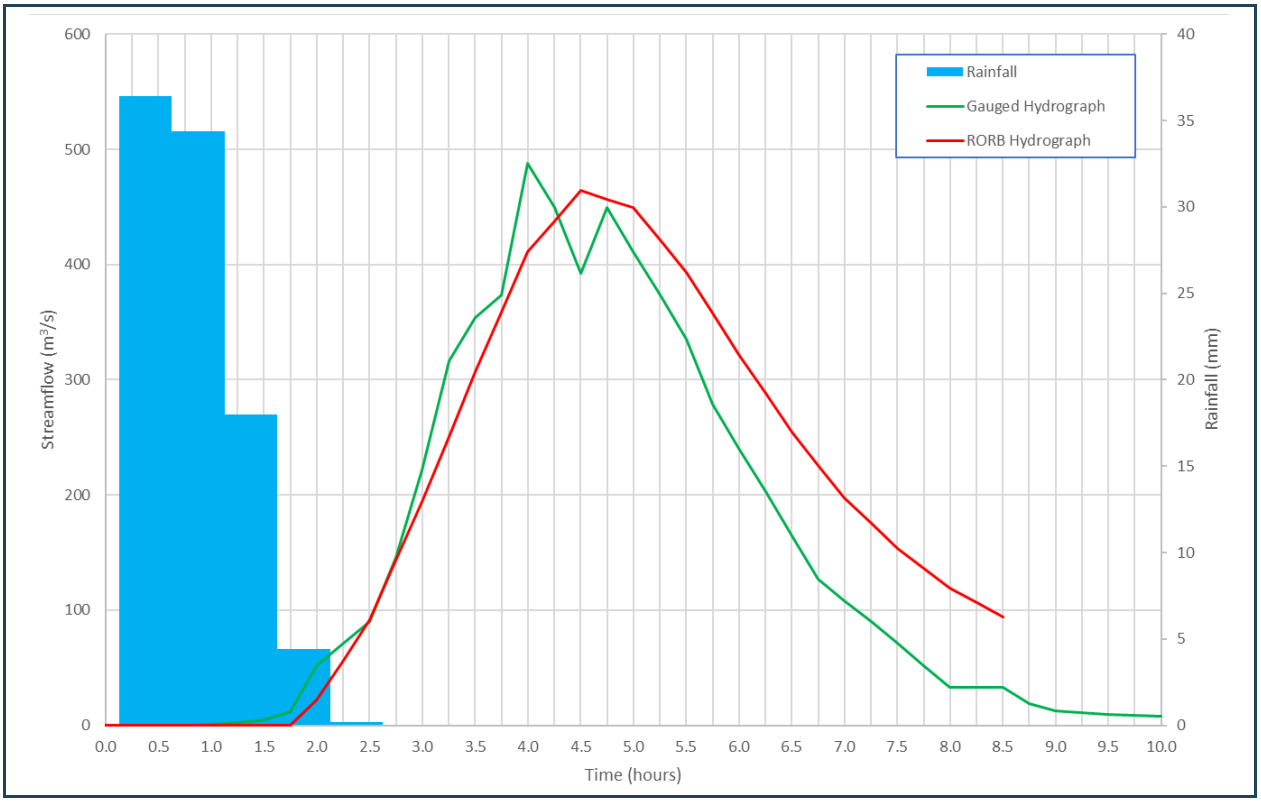


Figure 4.3 RORB Calibration Event at SWML01a from January 2020

The observed rainfall event used for this calibration (a 93.2 mm burst over 2 hours) was estimated to have an AEP of 5% over the 4-hour (approx.) critical duration for the catchment when compared to the site Intensity-Frequency-Duration (IFD) data from BoM (refer above Section 2.6).

Australian Rainfall and Runoff (AR&R) (Ball et al., 2019) flood estimation methodologies encourage the use of site-specific runoff coefficients derived from collected data over the use of regional loss estimates. As such, the loss parameters derived from the calibration exercise as outlined above have been adopted to estimate design flow hydrographs for catchment areas reporting to the boundary of the 2D flood model. [Note that different volumetric rainfall loss coefficients are used when completing water balance modelling of the claypans, as these were calibrated to volumes reporting to the claypans rather than peak flow rates].

The adopted rainfall loss parameters are lower than the regional estimates provided by AR&R and therefore the RORB model produces higher design flow rates when using these parameters compared with regional loss parameters provided by AR&R. A comparison of the peak flow rates estimated by RORB at SWML01 from the January 2020 rainfall event using the calibrated and other published rainfall loss parameters is shown in Table 4.2. The peak flow rate estimated in RORB with the adopted parameters is higher than those produced for the 5% AEP event using the Regional Flood Frequency Procedure (RFFP; Flavell, 2012) and the Regional Flood Frequency Estimate (RFFE, AR&R 2019). The higher runoff rates compared to the regional estimates reflect a degree of conservatism in the calibrated runoff estimates.

Table 4.2 Comparison of RORB Peak Flow Rates Calculated for SWML01a

Method	Peak Flow (m^3/s)
Measured/Gauged	488
Calibrated RORB	464
AR&R (1998) Parameters	342
AR&R (2019) Parameters	160
RFFP (5% AEP Flow Estimate)	232
RFFE (5% AEP Flow Estimate)	246

Rainfall loss parameters were also required to be applied (separately) to the rainfall hyetographs used within the rain-on-grid portions of the 2D flood model. This is discussed in more detail in Section 4.3.5.

4.3.3 Flood Model Catchment Definition

The baseline surface water catchments defined in Section 4.2 report to the boundary of the 2D flood model when LiDAR terrain data is not available for the full catchment area. Rain-on-grid hydrology cannot be simulated in the 2D flood model without the full catchment, instead, inflow hydrographs from RORB hydrological modelling were developed and used as inflows at the model boundary to simulate the relevant catchments inflows to the 2D flood model. Figure 4.4 depicts the catchments reporting to the 2D flood model boundary.

4.3.4 RORB Hydrological Modelling

RORB was used to generate design inflow hydrographs for each AEP event for two catchments in the Chichester Range (C1 and C2) and four catchments in the Hamersley Range (H1-H4) that extended outside of 2D flood model boundary as shown on Figure 4.4. Catchment C2 was considered representative of the remaining smaller Chichester Range catchments reporting to the 2D flood model boundary. The hydrographs for these catchments were derived from the C2 RORB model, with the C2 hydrograph scaled by relative catchment area. The design inflow hydrograph from the C1 RORB model was used for the westernmost Chichester Range catchment as it was of similar size.

The initial and continuing rainfall losses (IL and CL) of 35 mm and 5 mm/hr as calibrated previously was used across all design AEP events within the RORB model. The key parameters used in the RORB models are summarised in Table 4.3. The AR&R (Ball et al., 2019) Kc parameter calculation for the Pilbara was adopted for each catchment.

Table 4.3 RORB Parameters

Catchment	Catchment Area (km^2)	Catchment Equal Area Slope (m/km)	Adopted Kc (AR&R)
C1	147	2.4	9.7
C2	6	7.1	1.5
H1 (Wittenoom Gorge)	687	7.6	13.4
H2	126	10.2	6.3
H3	121	9.0	6.0
H4	641	5.6	19.3

For each of the six catchments which were modelled in RORB, the ensemble of synthetic rainfall hyetographs provided by ARR were run. To determine which hydrographs to include in the updated 2D flood model for each AEP event, box and whisker plots were developed as recommended by AR&R (Ball et al., 2019) for each catchment external to the 2D model domain. The RORB outputs and the box and whisker plots for each catchment were analysed as follows:

- The median, upper and lower peak flow rate outputs from RORB were collated for all durations across all AEP events.
- For each AEP event the highest median peak flow rate was compared to the box and whisker plots to determine a representative critical duration for each model. Note that different AEP events may have resulted in different critical durations for a given catchment.
- To select a single representative critical duration for all AEP events for each catchment, the storm duration that best encompassed the peak flow rates for all AEP events was chosen.
- The corresponding RORB hydrographs for each AEP event were then included as boundary inflows into the 2D flood model.

Note the following points with regards to this approach, which leads to conservatively high runoff rates in the 2D flood model:

- The inflow hydrographs to the 2D flood model are all generated from different storm events (in terms of duration and rainfall distribution through the storm). The likelihood that all of these critical storm events would occur concurrently across these catchments is low.
- An areal reduction factor has been applied within each of the RORB models to account for the fact that the rainfall is unlikely to be consistent across the full catchment area. In practice, a higher aerial reduction factor should be adopted for the full 2D flood model domain to account for the larger total model area and applied to each RORB model catchment.
- Within the 2D model, the inflow hydrographs are all timed to start concurrently. In reality, the timing of the rainfall event is unlikely to occur simultaneously across the full catchment area.

The representative critical durations assessed for Hamersley and Chichester Range catchments are reported in Table 4.4.

Table 4.4 Representative Catchment Critical Durations

Range	Hamersley Range				Chichester Range	
Catchment	H1 (Wittenoom Gorge)	H2	H3	H4	C1	C2
Representative Critical Duration (hours)	36	24	24	36	24	6

The corresponding RORB temporal pattern for the Chichester Range catchment closest to the Project (Catchment C2) for the 5% AEP was used to simulate the different AEP design rain-on-grid depths in the 2D flood model. This temporal pattern was chosen as the 2D flood model domain covers smaller catchment areas (compared to the RORB model) and therefore a shorter duration rainfall event is appropriate.

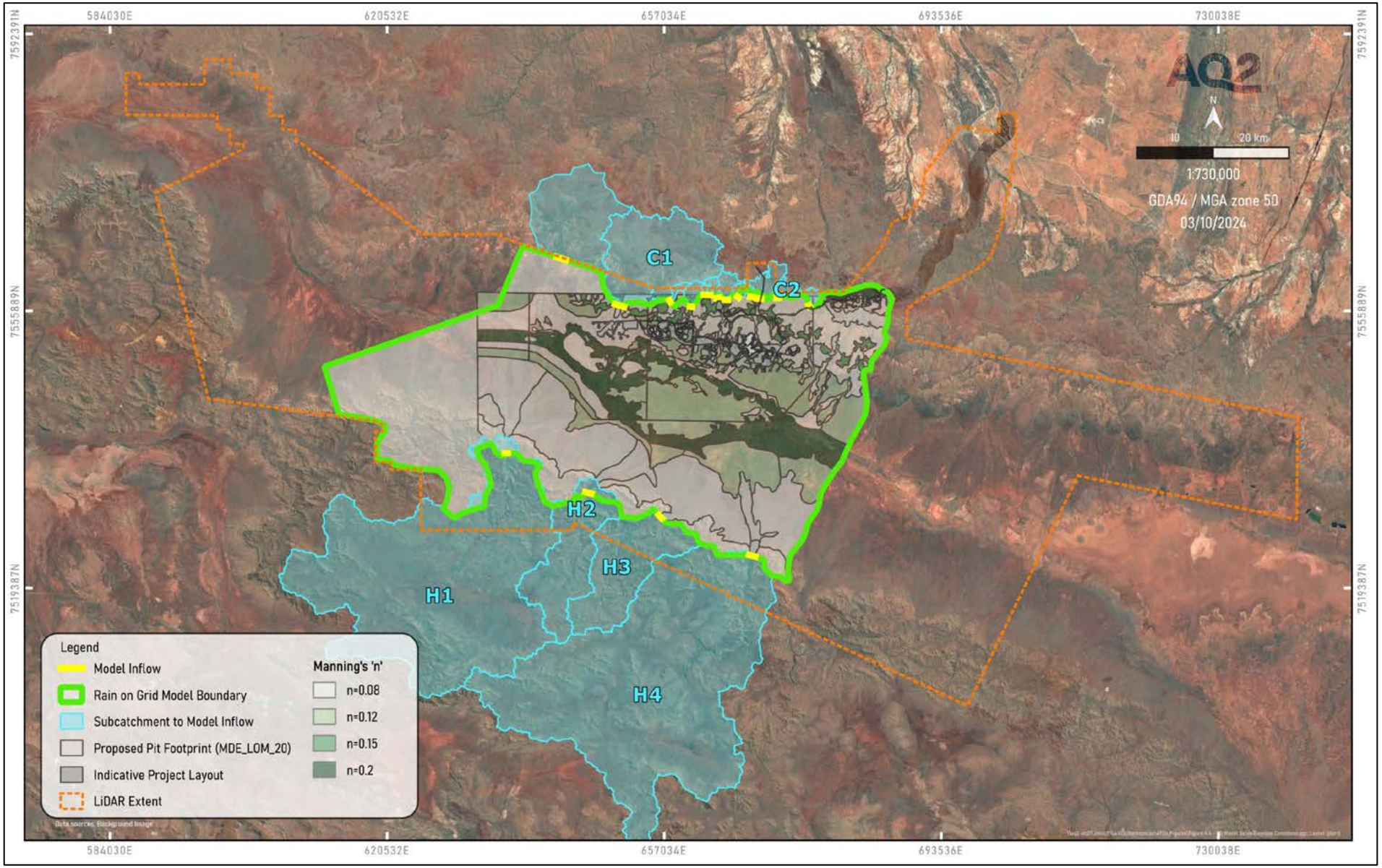


Figure 4.4 2D Model Setup Baseline Conditions

4.3.5 2D Flood Modelling

The 2D flood model was developed using the 2023 0.5x0.5 m LiDAR DEM to predict baseline inundation extents resulting from a range of design events (63%, 50%, 20%, 10%, 5% and 1% AEP). The 2D flood model domain generally falls within the extents of the area covered by the 2023 LiDAR data with some SRTM data used to supplement the upstream portion of smaller catchments that report to the haul road alignment (in the eastern part of the model). A comparison of the available LiDAR DEM data and the 2D flood model domain is shown in Figure 4.1. Inflow hydrographs at the model boundary were developed using RORB for catchments that extended outside the DEM extents within the Chichester and Hamersley Ranges (as discussed in Section 4.3.4).

The intent of the modelling is to provide baseline flood depths and flow velocities in the vicinity of the proposed mine disturbance area so that the impacts of the proposed Project on the surface water regime can be quantified. As such, the model domain was selected to ensure that the hydrological conditions in the vicinity of the disturbance area are appropriately simulated. The floor of the Fortescue Valley adjacent to the Disturbance Area is extremely flat (i.e. 10 m elevation fall over an 80 km total length spanning either side of the claypans which is ~0.01% slope) and contains numerous areas where water ponds. Given this, the eastern and western model boundaries were chosen as follows:

- Eastern model boundary – the Great Northern Highway was chosen as the model boundary to the east of Project. The road represents a local high spot across the valley with very little slope to the natural surface on either side of the road alignment. Any culverts beneath the highway or floodways over the highway would be expected to act more to distribute flows either side of the road rather than to convey large flow rates. As such, it is felt that not much flow will cross the highway and, in the model, no flow is allowed across this boundary (in or out of the model).
- Western model boundary – the western model boundary was chosen to be placed downstream of the Fortescue rail alignment. There is the potential that runoff building up behind the railway may impact the hydrological regime at the claypans such that the model boundary was selected to be positioned sufficiently downstream of rail alignment to allow the effect of this potential hydraulic control to be simulated.

A 2D flow area with a 50 m x 50 m grid was delineated within the model domain. Breaklines with a computational mesh spacing of 10 m by 10 m were applied to natural flow paths and proposed features such as roadways, bunds, embankment slopes, and rail formations. The break lines orient the computational mesh to align cell edges with the features reflected in the terrain surface. In this way, the diversion structures are being picked up in the modelling.

HEC-RAS recognises sub-grid terrain resolution, and the computation of flow transfer between individual grid cells accounts for the geometry of the underlying surface at the terrain resolution of 1 m by 1 m.

The general model build details are as follows:

- A 50 m x 50 m grid applied across the model with a refined grid of 10 m x 10 m applied to key surface water flow paths.
- Inflow hydrographs applied from upstream catchments that were generated using RORB.
- Rain-on-Grid hydrology applied across the model using a 6-hour rainfall event hyetograph generated using the AR&R design rainfall depths and temporal pattern as determined in Section 4.3.4.
- Model simulation duration of 5 days.
    - Note that, as discussed in Section 4.3.4, the critical storm duration of the larger catchments external to the 2D model boundary (which were simulated in RORB) were typically in the range of 24 to 36 hours. At the end of the model, runoff is still reporting to areas where ponding occurs in the Fortescue Valley (such as the claypans).

4.3.5.1 Roughness and Infiltration Parameters

Runoff responses within the Study Area will vary according to different landscape elements. To mimic this, different roughness and infiltration parameters were assigned to the defined ecohydrological units (EHUs) as assessed in Section 8. Each EHU represents a landscape element with broadly consistent and distinctive ecohydrological attributes, for example, (but not limited to) different runoff responses. Refer Table 4.5 for a summary description of each landscape EHU, including their potential roughness and infiltration characteristics, and a schematic locating each EHU within the Study Area. The roughness and infiltration parameters were varied as follows.:

- Manning's 'n' roughness value – higher Manning's 'n' values were applied to EHUs with denser vegetation and undulating microtopography to slow down the transport conveyance of runoff from these EHUs to the next EHU downstream. Flow depths in concentrated flow paths are increased where roughness values are higher. Figure 4.4 shows the spatial distribution of Manning's 'n' simulated in the 2D flood model.
- Infiltration rate – different rainfall infiltration losses were applied to the rainfall hyetograph within the model by assigning different infiltration models to each EHU. This allowed some EHUs to contribute a higher portion of the runoff to receptors (such as the Gnalka Gnoona and Koodjeepindarranna claypans) and for others to contribute less runoff (i.e. simulating increased local scale water storages, such as within the Fortescue Valley where loamy soils are present).

Infiltration losses within the 2D model domain were simulated using the Deficit and Constant Loss method. Table 4.4 shows the adopted Initial Loss and Continuing Loss values, which were applied in the model as Initial Deficit and Potential Percolation Rates, respectively for each of the EHU areas. A Maximum Deficit of 60 mm was applied to all areas (i.e. the maximum total rainfall loss in the model was 60 mm). Note that the initial losses shown in Table 4.4 are generally lower than those adopted in the RORB. This is because the initial loss used in the RORB model needs to account for both the initial soil infiltration loss and the storage losses (low points in the terrain), whereas the DEM used in the 2D flood model means the storage losses are accounted for within the model.

Spatially varying Mannings roughness coefficients were applied to each area as shown in Table 4.4.

Table 4.5 Summary of landscape ecohydrological units and 2D model parameters

EHU	Description	Relative rainfall storage	Initial Loss (mm)	Continuing Loss (mm/hr)	Mannings 'n'
Upland Rises	Peaks and upper hillslopes; shallow or skeletal soils overlying basement rocks.	Low	15	4	0.08
Upland Valleys	Broader depressions in the Chichester Range where sediments have accumulated, enabling runoff capture/storage and denser vegetation	High	20	6	0.15
Upland and Alluvial Fan Drainages	Channels that exit the Chichester Range and transmit across the gently sloping alluvial plains to the south of the range. Progressive loss of flow energy on exiting the range. Alluvial Fan Drainages support relatively dense mulga shrubland.	Moderate	20	6	0.08
Alluvial Fan Washplains	Banded vegetation on a gently sloping stony plain. Runoff is mostly generated locally and captured in the downgradient grove.	High	20	6	0.12
Valley Calcrete Plains	Broad unit of the valley floor. Variably dissected and overprinted by alluvium, giving rise to a subtle mosaic of rises and depressions.	Moderate (greater around the periphery of outcrops; less where local depressions prevent any spillover to adjacent areas)	15	4	0.12
Valley Stony Flats	Stony plains abutting the valley where slope (and hence runoff) is insufficient to support banded vegetation.	Low/Moderate	15	4	0.08
Valley Loamy Flats	Areas below the Stony Flats, where accumulated sediment and organic matter underpin better topsoil structure and high infiltration rates. These support dense patches of woodland and grassland vegetation; as determined by subtle changes in physical and chemical soil properties.	High	30	10	0.2
Valley Ponding Flats	The lowest depressions where water ponds; typified by high clay content topsoil that impedes infiltration.	Low	10	2	0.08
Basaltic Tablelands	Stony gilgai plains and grasslands with underlying vertisol clays soils that form deep wide cracks vertically from the surface once dried out. These cracks allow for high infiltration rates and minimal runoff until closed.	High	50	10	0.2

4.3.5.2 Modelling Approach

The modelling approach adopted is focused on providing baseline hydrological flood characteristics within local drainage lines immediately surrounding the proposed development during design storm events, but may not fully represent flooding within the full Fortescue Valley area (including the claypans) for the following reasons:

- The critical duration storm to cause flooding of the claypans is likely to be different to that being modelled for flooding of the local small catchments.
- No initial storage of water in the Fortescue Valley has been accounted for.
- The cumulative effects of a sequence of rainfall events have not been considered.
- The model has not been run until all runoff from the catchments has reported to the claypans.
- Evaporative or infiltration losses within the Fortescue Valley have not been allowed for.

Flood levels within the claypans have been addressed separately using a water balance approach (refer Section 4.4).

For the ponded water within the Fortescue Valley ESA (refer Section 1.7), the environmental impact assessments informed by the flood model are considered valid as the full catchment area reporting to the ponding area is being simulated within the flood model domain. Any changes to the ponded water level regime as a result of mine development are considered to be realistic. It is unlikely runoff within the Fortescue Valley from the east of the Study Area would contribute to the ponding in small rainfall events. If these events did contribute runoff then the impact of the Project on hydrological changes would be reduced and hence the approach taken is suitably precautionary.

4.3.6 2D Flood Modelling Results

The baseline maximum flood depths and flow velocities predicted by the 2D flood model for the design rainfall events are presented in Appendix A. Note the 2D flood model maps are screened to only show predicted flood depths that exceed 0.05 m.

Key observations from the 1% AEP flood predictions for baseline conditions are:

- The majority of the proposed mine infrastructure is located along the Chichester Range and alluvial fans to the north of the Fortescue Valley. Across the alluvial fans, infrastructure would be exposed to extensive shallow sheetflow across the floodplain and braided channels branching over the fans.
- A number of upstream catchments drain towards the Fortescue Valley from the north and flow through the Study Area as defined watercourses. Flood depths in these channels can exceed 1.5 m. The proposed Fridge Central / Horseshoe West mining infrastructure areas appear more susceptible to these flows given its proximity and relatively compact layout.
- Extensive flooding across the claypans is predicted, with areas of widespread ponding occurring. The flood maps also show the claypan inundation extents as predicted from the water balance model for the 1% AEP rainfall event. This flood level is unlikely to occur simultaneously with the predicted 1% AEP flood depths from the 2D flood model as they may be driven by different flood mechanisms, for example, storm duration or consecutive runoff events. The 2D flood model does not simulate these flood mechanisms and thus the predicted depths within the claypan are limited and likely underestimated. For flood depth predictions specific to the claypans refer to Section 4.4.7.

The extent of inundation and predicted flood depths are reduced for the smaller AEP events. The maximum predicted flood depths for the 10% AEP event show the flow primarily confined to defined drainage channels with less flow across the floodplains. For the 20%, 50% and 63% AEP events, the maximum predicted flood depths are contained within the channels and discrete areas of ponding within the valley are observed, generally, only interconnected by very shallow flood depths.

In the 63% AEP event, interplay of different EHUs on water movement in the landscape can be observed. For example, Figure 4.5 shows a relatively large ponding area (Point A) that occurs at the termini of two coalescing drainage tracts exiting the alluvial fans. The flood model results (which use EHU specific Manning's n and infiltration parameters) predict the following observed flood behaviour:

- Water accumulating on the low infiltration Stony Flats EHU with resultant fine sediment deposition.
- Water shedding onto the adjacent Loamy Flats EHU and then rapidly infiltrating; these areas support denser vegetation.
- Further ingress of flood water into the valley as influenced by microtopography and ultimately prevented by the Calcrete Plain barrier area to the southwest.

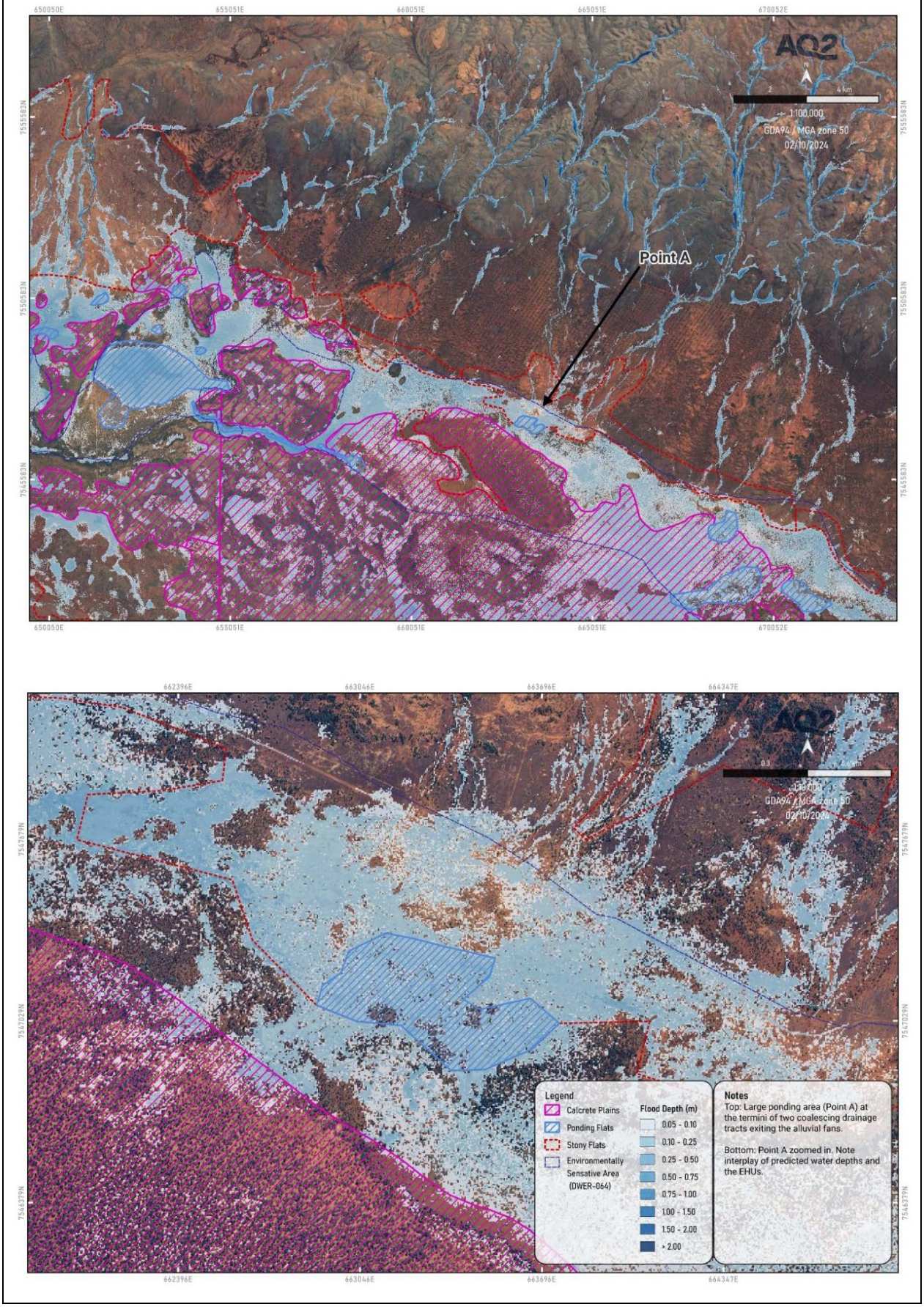


Figure 4.5 2D Model Predicted 63% AEP Maximum Flood Depths and EHUs

Outputs from the 2D flood model were used to quantify parameters in the water balance model of the Gnalka Gnoona and Koodjeepindarranna claypans. With reference to the claypan catchments discussed further in Section 4.4.1 and shown in Figure 4.6, the potential for runoff contribution to Koodjeepindarranna Claypan from the Chichester and Hamersley ranges was quantified from the 2D flood model results across various AEP events. Runoff from (refer Figure 4.6) Catchment E and Catchment L (Wittenoom Gorge) was simulated in the 2D flood model using the peak inflow hydrographs from RORB as discussed in Section 4.3.4. For entire catchment responses to the various AEP events, it was predicted that, on average, 68% of runoff from Catchment E and 15% of runoff from Catchment L contributed to Koodjeepindarranna Claypan and the remaining runoff reports to the Fortescue Valley downstream of the Koodjeepindarranna Claypan. These predicted flow splits were used to quantify the approximate runoff volumes reporting to Koodjeepindarranna Claypan as described further in Section 4.4.1.

The 2D flood model results also predicted some runoff from Catchment K and J can contribute to Gnalka Gnoona Claypan in large AEP events (1% AEP), however flood flows predominantly report further downstream to Koodjeepindarranna claypan. In the water balance of the claypans, catchments K and J were assumed to report to Koodjeepindarranna Claypan.

Inflows from two Hamersley Range catchments that were simulated in the 2D flood model (H3 and H4 in Figure 4.4) were excluded from the water balance of the claypans upon inspection of the 2D flood model results, 2023 LiDAR DEM and aerial imagery. Between the catchment termini into the Fortescue Valley and Gnalka Gnoona claypan, drainage is poorly defined and throughflow is impeded by local depressions and calcrete barriers. Preferential flow paths from catchment H3 and H4 were primarily predicted to contribute to the loamy and ponding flats upstream of the calcrete barrier.

4.4 Claypan Water Balance

A water balance of the Gnalka Gnoona and Koodjeepindarranna claypans was completed to define the baseline hydrological regime of the claypans and to predict potential flood levels that may occur due to water storage within the claypans. To complete the water balance, the following steps were taken:

- Definition of catchment boundaries reporting to each of the claypans based on interpretation of elevation data, aerial photography and the 2D flood model results.
- Analysis of collected water level data.
- Development of a water balance model.
- Run a short-term calibration model to match modelled water levels to recorded data.
- Run a longer-term calibration model to match modelled water levels with observations from historic satellite imagery.
- Flood frequency analysis of the modelled water levels from the longer-term calibration model.

4.4.1 Claypan Catchment Boundaries

The maximum potential catchment areas which may report to the claypans are discussed in Section 2 and are nominally shown in Figure 4.6. There is uncertainty when defining the boundaries of the surface water catchments draining to the claypans due to the following reasons:

- The Fortescue Valley floor in proximity to the Study Area is extremely flat (i.e. 10 m elevation fall over an 80 km total length spanning either side of the claypans which is ~0.01% slope) and drainage channels along the floor of the valley are poorly defined. There is also evidence of ponding due to the valley floors microtopography, which would prevent runoff from contributing to downstream flow until available storages are full. This makes it difficult to define the extent of the Fortescue Valley floor which would contribute runoff to the claypans from the south and east as it may vary depending on the size of the rainfall event and antecedent conditions. It has been assumed that the effective claypan catchments extend only a limited distance upslope along the Fortescue Valley floor.

- Where drainage lines exit from the Chichester and Hamersley Ranges, extensive alluvial fans have formed with braided preferential flow channels that distribute runoff across them. Some of the fans are positioned such that runoff from the upstream catchment may or may not report to the claypans depending on the position of the preferential flow channel for a particular event.

Effective catchment areas reporting to the claypans were adopted to account for the microtopography in the Fortescue Valley and preferential drainage paths on the alluvial fans as defined in the 2023 LiDAR DEM. The results of the 2D flood modelling exercise (discussed in Section 4.3) were used to assist in defining the effective catchment areas for the claypans, which are shown on Figure 4.6 and detailed in Table 4.6. The catchments were split into "Chichester" catchments, "Hamersley" catchments and "Valley" catchments as the rainfall loss parameters applied to the steeper, rocky Chichester and Hamersley Ranges would be different to those applied to the flat, vegetated Fortescue Valley area.

The following should be noted:

- Discharge from catchment area E has nominally been split to be 68% to Koodjeepindarranna and the remainder to discharge downstream of the claypans, based on the 2D flood model results.
- Discharge from catchment area F has nominally been split to be 90% to Koodjeepindarranna and 10% to Gnalka Gnoona, based on inspection of aerial imagery.
- It has been assumed that only catchments L and K from the Hamersley Range drain to the claypans. Runoff from the other potential Hamersley Range catchments (refer Figure 3.4) have been assumed to collect within the Fortescue River Valley and not reach the claypans.
- Discharge from catchment L (Wittenoom Gorge), has been split such that 15% reports to Koodjeepindarranna Claypan and the remainder is assumed to discharge downstream of the claypans, based on the 2D flood model results.
- It has been assumed that existing linear infrastructure development within the claypan catchment areas (such as the rail lines and roads) have not altered the contributing catchment areas to the claypans. These features have been picked up in the 2023 LiDAR data and were included in the 2D model domain, with gaps in the linear infrastructure landforms made in the model surface to simulate culverts where these are apparent in aerial photography. The 2D model simulated the impact of these features on the natural runoff which was used to define claypan catchment areas.
- The total effective claypan catchment areas which have been adopted in the water balance model are 817 km^2 (Koodjeepindarranna) and 215 km^2 (Gnalka Gnoona).

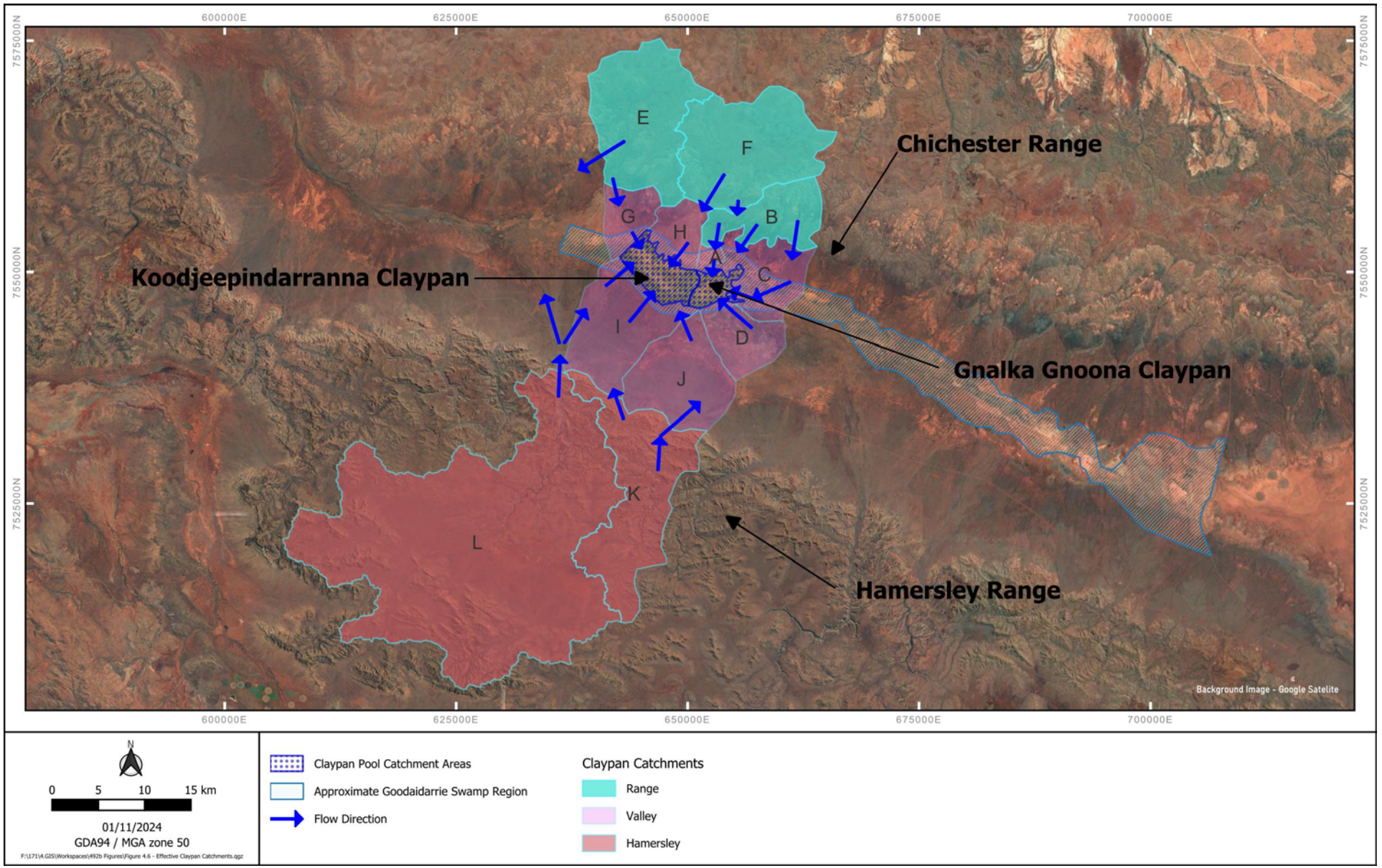


Figure 4.6 Effective Claypan Catchments

Table 4.6 Effective Claypan Catchments (Pre-Development)

Catchment ID	Reporting to Koodjeepindarranna Claypan (km^2)	Reporting to Gnalka Gnoona Claypan (km^2)	Reporting Downstream of Claypan (km^2)	Catchment Type
A	-	6	-	Valley
B	-	63	-	Range
C	-	65	-	Valley
D	-	49	-	Valley
E	101 (68% of Catchment)	-	48 (32% of Catchment)	Range
F	140 (90% of Catchment)	16 (10% of Catchment)	-	Range
G	35	-	-	Valley
H	34	-	-	Valley
I	106	-	-	Valley
J	99	-	-	Valley
K	165	-	-	Hamersley[#]
L	103 (15% of catchment)	-	586 (85% of catchment)	Hamersley[#]
Koodjeepindarranna Claypan Footprint	34	-	-	Valley
Gnalka Gnoona Claypan Footprint	-	16	-	Valley
Total	817	215	634	

[#] Note that within the model, the rainfall losses for Valley catchments were applied to the Hamersley catchments, K and L.

4.4.2 Water Level Data Assessment

As discussed in Section3.1, the baseline surface water monitoring network included pressure transducers installed within the claypans; specifically, SWML03 installed in Koodjeepindarranna Claypan and SWML04 installed in Gnalka Gnoona Claypan. The baseline data was assessed as follows:

- Pressure transducer measurements were converted to a calculated water depth accounting for recorded barometric pressure readings.
    - Note barometric pressure data is not available for the period between January 2022 to February 2023. As a result, corrections of the water level data during this period were not completed, resulting in additional uncertainty in the observed data during this period (such as the claypan inundation event in early 2020).
- The water depths were converted to a relative level using surveyed elevations of the installation locations and measurements of cable lengths which support the pressure transducers.
    - Note that there was a significant discrepancy (0.29 m) between the surveyed ground level at SWML03 (Koodjeepindarranna Claypan) compared to the DEM elevation at the SWML. The surveyed elevation has been discarded as it is not consistent with the distribution of ponded water within the claypans shown in historic imagery, which indicated that the elevation of the SWML is similar to the lowest elevation within the claypan, consistent with the DEM but not the survey data. The DEM elevation was therefore used. However, if the DEM at the SWML03 location

is not representative of the actual elevation of the logger, the calibration of the claypan water balance model will be affected.

- Stage vs storage curves for each of the claypans were developed using the latest (2023) LiDAR DEM to convert the measured water levels into stored volumes within the claypans. The following observations are made:
  - It appears that vegetation may be picked up within the DEM, rather than the ground surface. Particularly in Koodjeepindarranna Claypan, which is more heavily vegetated, the conversion of measured water levels would therefore result in reduced estimates of stored volume within the claypan when the stage vs volume curve is applied.
  - A drainage channel links the Koodjeepindarranna and Gnalka Gnoona Claypans with a high point that needs to be overtopped before water can flow between them. The elevation of this high point is 402.9 mRL based on the DEM, which was used as part of the boundary between the claypans when defining the stage vs storage curves.
  - Based on the DEM, the Koodjeepindarranna Claypan appears to overflow further downstream when lake water levels exceed 403.5 mRL. This overflow point has been used as part of the boundary when defining the stage vs storage volume curve.
- The measured water level elevations were converted to storage volumes using the stage vs volume curves.

4.4.3 Water Quality (TDS) Data Assessment

The baseline surface water monitoring network included monitoring stations within the two claypans, which recorded electrical conductivity (EC) readings at 15-minute increments. These readings have been converted to approximate salinity (as TDS) to provide data on how the salinity of the claypans changes following runoff events.

Timeseries plots of the recorded salinity within the claypans are shown on Figure 4.7 and Figure 4.8. Key observations from the recorded data are as follows:

- When runoff first reports to the claypans, the salinity of the ponded water is typically low (<100 mg/L).
- As the water in the claypans evaporates and the salts are left behind, the salinity of the claypans increases.
- Maximum TDS values from the observed data are less than 900 mg/L.

Further water quality analysis is discussed in Section 4.5.

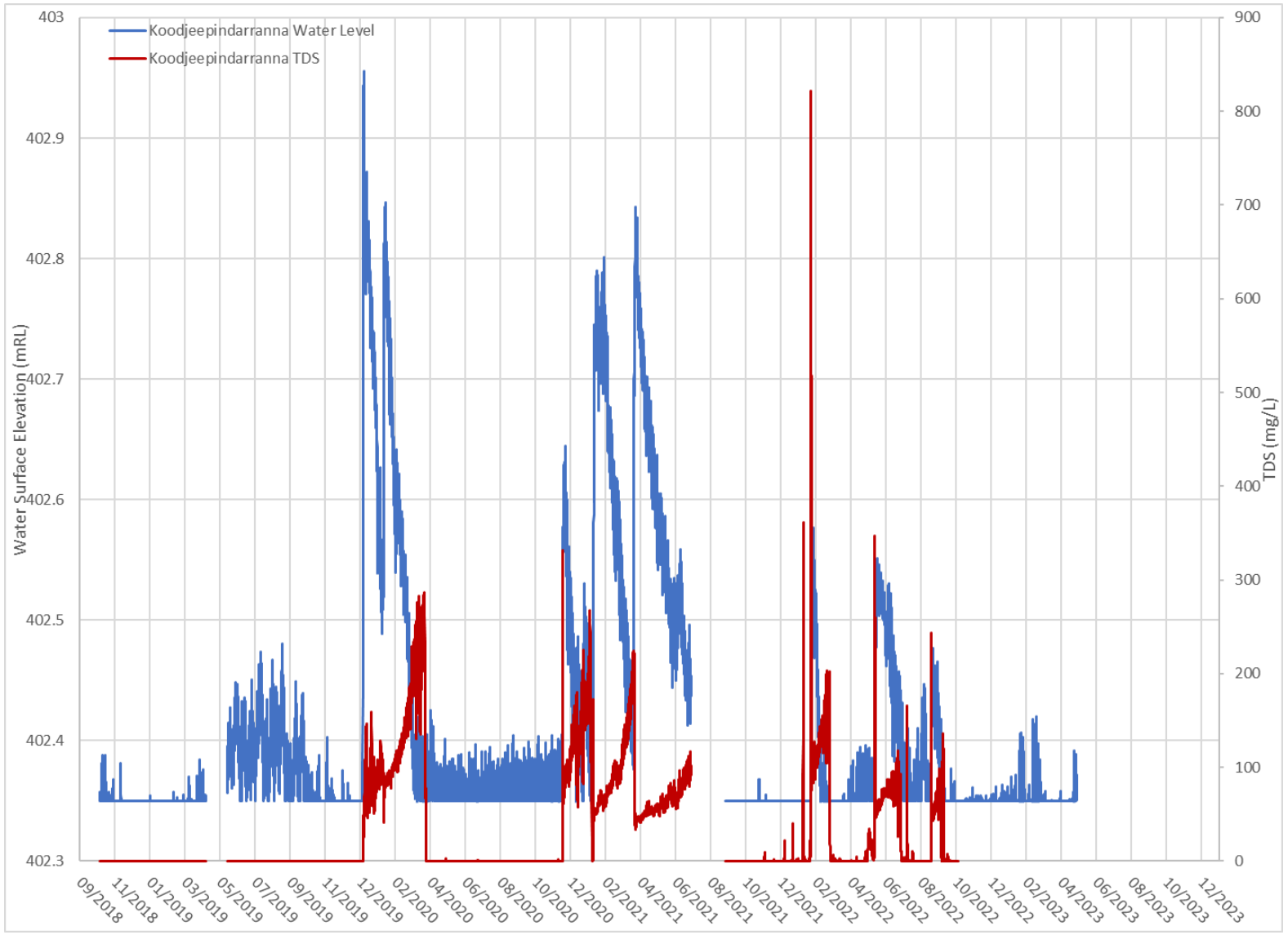


Figure 4.7 Koodjeepindarranna Claypan Salinity Measurements

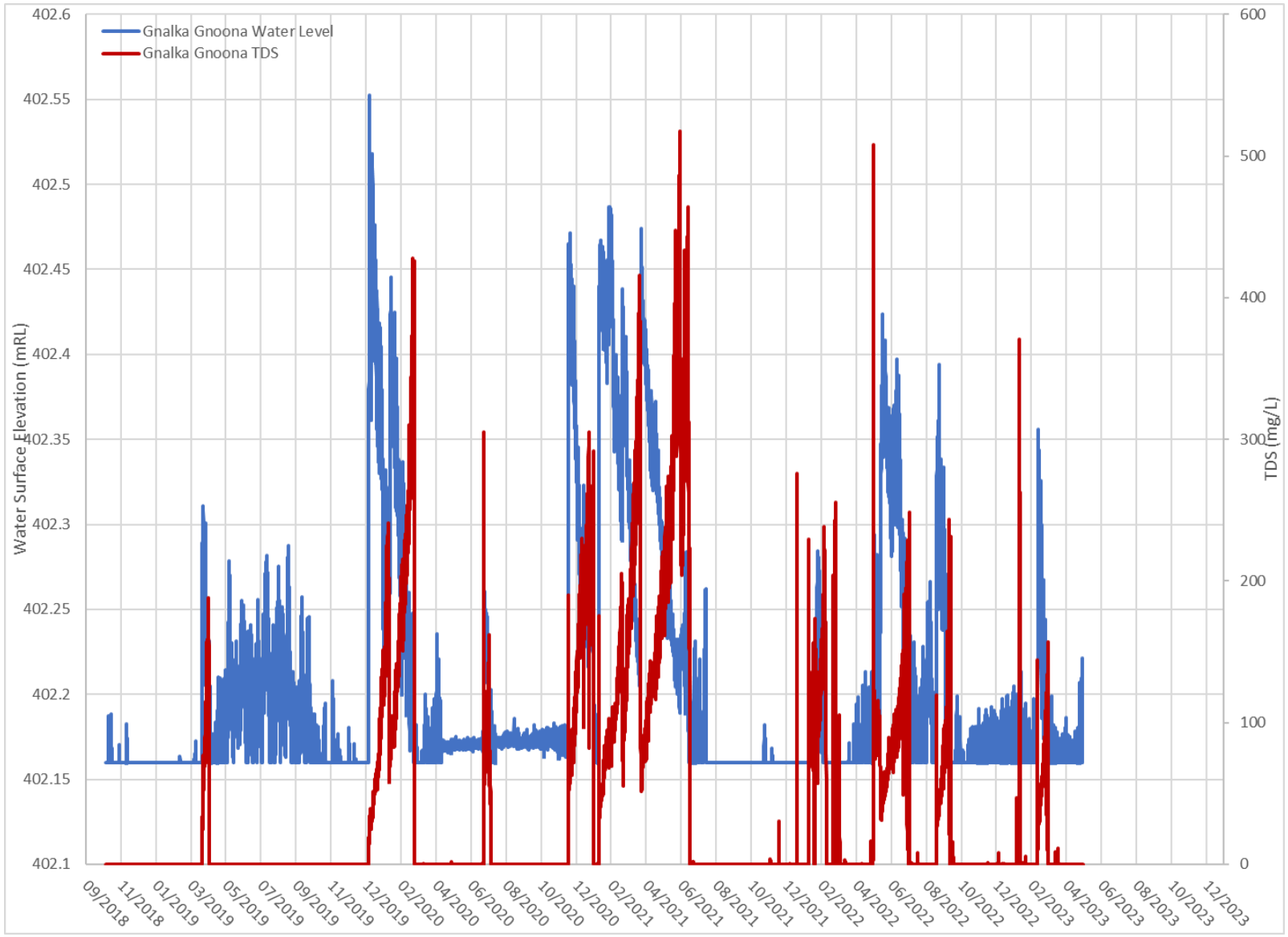


Figure 4.8 Gnalka Gnoona Claypan Salinity Measurements

4.4.4 Water Balance Model Development

A water balance for each claypan was created in GoldSim and completes water balance calculations on a daily timestep, consistent with the recorded rainfall data. The stored water volume is calculated at each time step by adding new inflow volumes to the storage volume from the previous time step and subtracting the outflow volume:

$$Storage\ Volume = Storage\ Volume_{Previous} + Inflows - Outflows$$

The water balance model which has been developed covers both claypans using similar calculation logic, but different inputs based on observed behaviour. Inflows to the claypans include runoff from the defined effective catchments and rainfall directly onto the surface of water ponded in the claypan. Water losses from the models are via evaporation from the ponded water surface area, and infiltration/seepage to groundwater from across the ponded surface area.

The following input parameters were used:

- Claypan effective catchment areas (as shown in Figure 4.6).
- Stage/area/volume relationships for each claypan at 0.1 m elevation increments derived from the DEM data developed by Aerometrex Ltd for the Project and surrounding areas and provided to AQ2 by HPPL.
- An extract of the baseline daily rainfall data set was used (1922 onwards) as many data records were missing pre-1922 (refer Section 2). The extract consisted of:
  - Mulga Downs (BoM) rainfall data from 1922 to 2018;
  - Mulga Downs Exploration Camp (MDEC) rainfall data from 2018 to December 2023;
  - Karijini North (BoM) data between 2018 and January 2023 where MDEC data was not available.
- Average monthly dam evaporation loss rates sourced from Department of Agriculture for Mt. Tom Price (Luke *et al.*, 2003).
- Calibrated rainfall loss coefficients Initial Loss (IL) and a Proportional Loss (PL) function as discussed further in Section 4.4.5.1.
- Lake infiltration/seepage loss rate as calibrated in the model (refer Section 4.4.5).
- The elevation of the high point separating Koodjeepindarranna and Gnalka Gnoona claypans is 402.9 mRL. The model includes the following logic:
  - When the water level in only one of the claypans exceeds the interconnecting overflow level, 40% of the stored water volume above the overflow elevation is transferred to the other claypan.
  - When the water level in both claypans exceeds the interconnecting overflow level, 40% of water from the claypan with the higher water level is transferred to the claypan with the lower water level. Over a few days, the water levels in the two claypans typically equalises.
  - The factor of 40% is a nominal number to prevent model instabilities which may occur from water overflowing back and forth between the claypans if a high percentage was adopted.
- Water surface elevation and flow rate predictions extracted from the 2D flood model were used to develop a rating curve to define the outflow rate from Koodjeepindarranna claypan when predicted water levels in the claypan exceed 403.5 mRL (the elevation at which the Koodjeepindarranna claypan overflows downstream through the Fortescue Valley).
- A function to nominally transfer water between the Gnalka Gnoona and Koodjeepindarranna claypans when the water level in either claypan is above the high point separating the claypans was also adopted to balance (over time) the water levels within the claypans following large rainfall events. The purpose of the function is to achieve similar water levels in the two claypans following a large rainfall event when the two claypans are in hydraulic connection. The function transfers (nominally) 7% of the volume that represents the difference in claypan water levels each day, noting that larger rates of water transfer led to risks of numerical instabilities occurring in the model results.

4.4.4.1 Rainfall Losses

Modelled runoff to the claypan catchments within the water balance model responds to historic daily rainfall records, which are measured over a fixed 24-hr period, and centred 7-day rainfall totals (R_7) that account for past and upcoming rainfall days. Centred rainfall totals were used as the magnitude of these events were found to correlate to the largest observed inundation events in the claypans as assessed from historical satellite imagery. Runoff to the claypans results from excess rainfall across the upstream catchments after accounting for the following conceptual losses:

- Initial Loss (IL) at the start of a storm event that must be exceeded before any runoff can occur (considering storage within the valley and range catchments). For example, an IL of 100 mm effectively means that no runoff is generated into the claypan for any daily rainfall events which do not exceed 100 mm.
- Subsequent continuing runoff co-efficient (ROC), as a function of the centred 7-day rainfall total (R_7). This is applied to any remaining rainfall within the event that exceeds the IL. The ROC is calculated with a function based on the R_7 value and is used for all the catchment types. The result of the function is a ROC which increases the percent of rainfall that runs off as the size of the event increases. This was required when calibrating the model to approximate the claypan response to both small and large rainfall events.

The rainfall losses adopted were determined during a calibration exercise as discussed in Section 4.3.4, with losses due to evaporation and seepage from the claypan water volume accounted for separately in the model.

The modelling assumes 100% of rainfall falling on the ponded claypan surface water area reports to the pond storage volume (no losses).

Antecedent moisture conditions were simulated in the model by considering that rainfall recorded during previous days reduces the IL applied to a subsequent day's rainfall. This running IL value fluctuates between the full IL value and zero throughout the simulation period depending on the sequence of daily rainfall totals. The way the antecedent moisture conditions within the model are simulated to predict runoff volumes is summarised as follows:

- A running IL value varies between the full IL value and a loss of 0 mm throughout the model depending on the rainfall sequence.
- At the start of the model, the full IL is applied as the running IL until the first day of rainfall occurs.
- If the day's rainfall total is higher than the IL value, the IL value is removed from the total and the ROC applied to the excess rainfall. The IL that will apply to the following day's rainfall (if any) will be zero and the ROC will be applied.
- If the daily rainfall total is less than the IL value, no runoff occurs and the running IL value which would apply to the following time step is reduced by the rainfall depth. For example, for a nominal IL value of 100 mm, a daily rainfall total of 60 mm will reduce the running IL value for the next time step to 40 mm.
- If the rainfall total for the following day is less than the running IL value, the running IL value is further reduced by that day's rainfall depth. For example, a rainfall total of 20 mm would further reduce the running IL value from 40 mm to 20 mm.
- For days with no rainfall, the running IL value increases by a set amount (refer Section 4.4.5.1).
- The full IL is enforced again following sufficient successive days of no rainfall to increase the running IL value back to the full value.

4.4.4.2 Water Storage Volume

As outlined above, the claypan storage volume at the start of a timestep is defined as the stored volume from the start of the previous timestep plus (or minus) the difference between inflows and outflows over the timestep. The calculated storage volume is subsequently used to define the lake surface area, depth and relative level using lookup tables derived from the DEM. Note that the elevation at which the water levels were measured within the claypans was not at the lowest elevation as per the DEM, but the volume of water stored below the measurement point is relatively small.

4.4.4.3 Water Quality

In parallel to the water balance model operation, a salt mass balance model has been run within the GoldSim model. Each water flux within the model has an assigned TDS concentration which allows the mass of salt to be balanced in each of the claypans. A TDS in the claypans is calculated at each timestep by dividing the mass of salt (from the salt balance) by the volume of water in the claypan (from the water balance).

The assigned TDS concentration for each flux in the model is summarised as follows:

- Direct rainfall on the claypan lake surface: 1 mg/L (nominal).
- Runoff from the catchments: 50 mg/L (typical value to approximate salinity monitoring results).
- Evaporation loss from the claypans: 0 mg/L.
- Seepage loss to the groundwater: calculated TDS concentration for the claypan.
- Overflow from the claypan: calculated TDS concentration for the Koodjeepindarranna claypan.
- Overflow between the claypans: calculated TDS concentration for the claypan which is overflowing.

4.4.5 Calibration Runs

The following calibrations were completed for the water balance model:

- A short-term calibration to determine rainfall loss coefficients by matching model predictions to the observed water levels from the claypan surface water monitoring stations as detailed in the Section 3.
- A longer-term calibration to confirm the rainfall loss coefficients derived from the short-term calibration also predicted appropriate responses to significant rainfall events, based on reviewing historic aerial imagery, as these were limited in the short-term calibration period.

4.4.5.1 Short-Term Calibration Run

The purpose of the short-term calibration was to define IL and ROC parameters such that the model's peak water level predictions for the claypans closely approximated measured water levels. The same rainfall losses were applied to both claypans for the different types of catchments (refer Table 4.7) but the seepage loss rates were modified individually to allow the modelled water levels to approximate the observed recession following a runoff event. A seepage loss of 2 mm/day was applied to Koodjeepindarranna (SWML03) and 5 mm/day to Gnalka Gnoona (SWML04). The calibration was completed against data collected between late 2018 and mid-2023.

Table 4.7 Water Balance Rainfall Loss Parameters

Parameter	Catchment		
	Chichester	Valley	Hamersley[#]
Initial Loss	90 mm	120 mm	120 mm
Runoff Coefficient (%)	$0.15R_7 + 7.5$	$0.15R_7 + 7.5$	$0.15R_7 + 7.5$
Initial Loss Recovery	15 mm/d	10 mm/d	10 mm/d

[#] Note that within the model, the rainfall losses for Valley catchments were applied to the Hamersley catchments, K and L.

A comparison of the calibrated model results to the observed water levels in the claypans is shown in Figure 4.9 and Figure 4.10. The following observations are made, noting that other combinations of rainfall loss parameters could have been chosen which would allow the model to replicate the observed claypan water levels:

- The SWMLs in each claypan were not positioned at the lowest point. The modelled and observed water levels could therefore not be compared once the modelled levels fell below the surveyed elevation of the sensor at the SWML.
- A rainfall event of close to 100 mm was measured in January 2019 without any water volume in the claypans recorded above the pressure transducers. This served as the basis for the IL parameters adopted in the water balance model.
    - It is noted that this rainfall event may have only occurred over part of the claypan catchment and was the first rainfall event following a prolonged drought (refer Section 2). As such, it is possible that the IL adopted in the model may be over-estimated. However, when lower IL were used in the model, the model predicted the claypans to be inundated more frequently and at greater depths than the observations suggested.
- To achieve a reasonable model approximation of observed claypan water level responses, the runoff responses to the claypan were spread over a few days following the rainfall event, which mimics the time taken for runoff to report to the claypans from the upstream catchment areas. The effect of spreading out runoff reporting to the claypans was that the claypan ponded water surface area (where 100% of runoff reports to the claypan) was smaller in the days following a rainfall event, when the likelihood of additional rainfall is likely. The following percentage of runoff in each day from the recorded rainfall event was as follows:
    - Day zero – 20%
    - Day one - 50%
    - Day two – 15%
    - Day three – 10%
    - Day four - 5%
- Within the baseline data collection period, significant rainfall events occurred during the 2019/2020 and 2020/2021 wet seasons. Observed data from the claypan surface water monitoring stations for the 2019/2020 wet season showed the highest water level responses in the claypans in January 2020 (maximum values of 402.95 mRL in Koodjeepindarranna Claypan and 402.65 mRL in the Gnalka Gnoona claypan). This response is inconsistent with the baseline rainfall dataset extract as greater rainfall depths appeared to have occurred in the 2020/2021 wet season compared to the 2019/2020 wet season. Note that the 2019/2020 wet season followed a prolonged period of soil water depletion and drought stress between June 2018 and February 2020 (as discussed in Section 2).
- The 2020/2021 wet season predicted water levels in Koodjeepindarranna are relatively higher than those in Gnalka Gnoona and they exceed the overflow elevation between claypans. Within the water balance model, this results in the transfer of water from Koodjeepindarranna to Gnalka Gnoona and causes the predicted water levels in Gnalka Gnoona Claypan to be higher what would be predicted from rainfall/runoff from Gnalka Gnoona's direct catchments.
- The water balance model could not be configured to simulate the peak water levels across all events in the short-term calibration period as the magnitude of the observed runoff response did not match the magnitude of the rainfall in all instances.

- The recorded rainfall data is a measurement of rainfall at a single point and may not be representative of rainfall across the full claypan catchment areas. It is assumed that the rainfall records for the 2019/2020 wet season were more representative of rainfall over the entire catchment than the 2020/2021 and 2021/2022 wet season and therefore the rainfall loss parameters were calibrated predominantly for this data set. As a result, the water balance model overpredicts the 2020/2021 and 2021/2022 wet season claypan water levels and underpredicts events mid-2022.

The adopted IL for the Valley catchments are higher than for the Chichester catchments. The higher losses within the Valley catchments were applied given the lack of defined drainage shown on the LiDAR DEM within the Fortescue Valley, which indicates relatively slow runoff responses and large catchment storages that need to be filled before runoff to the claypans occurs. The steeper Chichester catchments will be more responsive to runoff and have less catchment storage losses and therefore a higher rate of runoff is expected. Further:

- The IL in the Chichester catchments (90 mm) is the equivalent of less than a 24-hr 20% AEP event (refer Figure 2.10, in Section 4.3 for IFD). The applied running IL recovery of 15 mm/d means that, following a runoff event, the running IL value in the model returns to the full value of 90 mm after 6 consecutive no-rain days.
- The IL in the Valley catchments (120 mm) is the equivalent of a 24-hr 20% AEP event. The IL recovery of 10 mm/d means that, following a runoff event, the running IL value returns to the full value of 120 mm with 12 consecutive no-rain days, reflecting the ponding storage that is likely to occur within the Valley area.
- There is greater uncertainty in the definition of the catchment areas within the Valley area than in the Chichester Range (both temporally and spatially). The higher rainfall losses applied to the Valley catchments reduces the impact of this uncertainty on the model calibration.

The rainfall losses from the Valley Catchments were also applied to the Hamersley Catchments, K and L, even though the runoff generation characteristics within the Hamersley Range are likely to be similar to the Chichester catchments. The higher rainfall loss parameters were applied given the distance the runoff from the catchments needs to flow through before reaching the claypans. This is attributed to the microtopography and limited slope throughout the Fortescue Valley as discussed in previous sections.

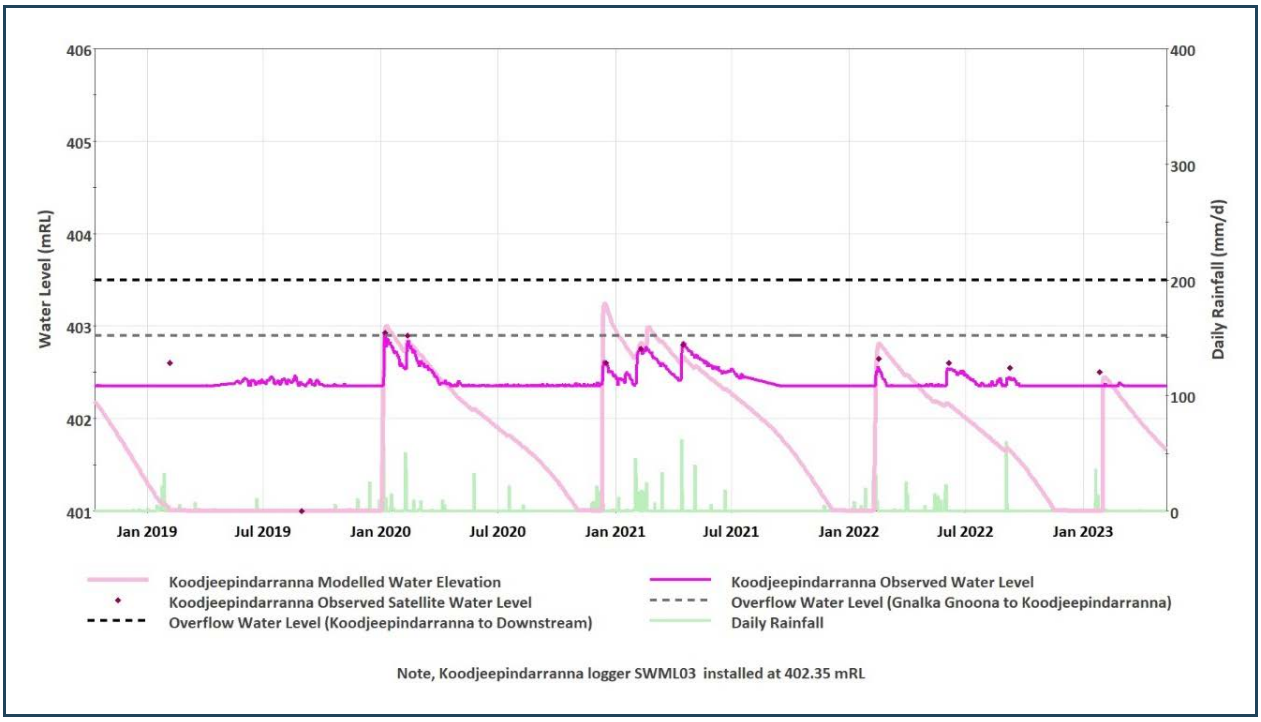


Figure 4.9 Short-Term Calibration – Koodjeepindarranna Claypan Water Levels

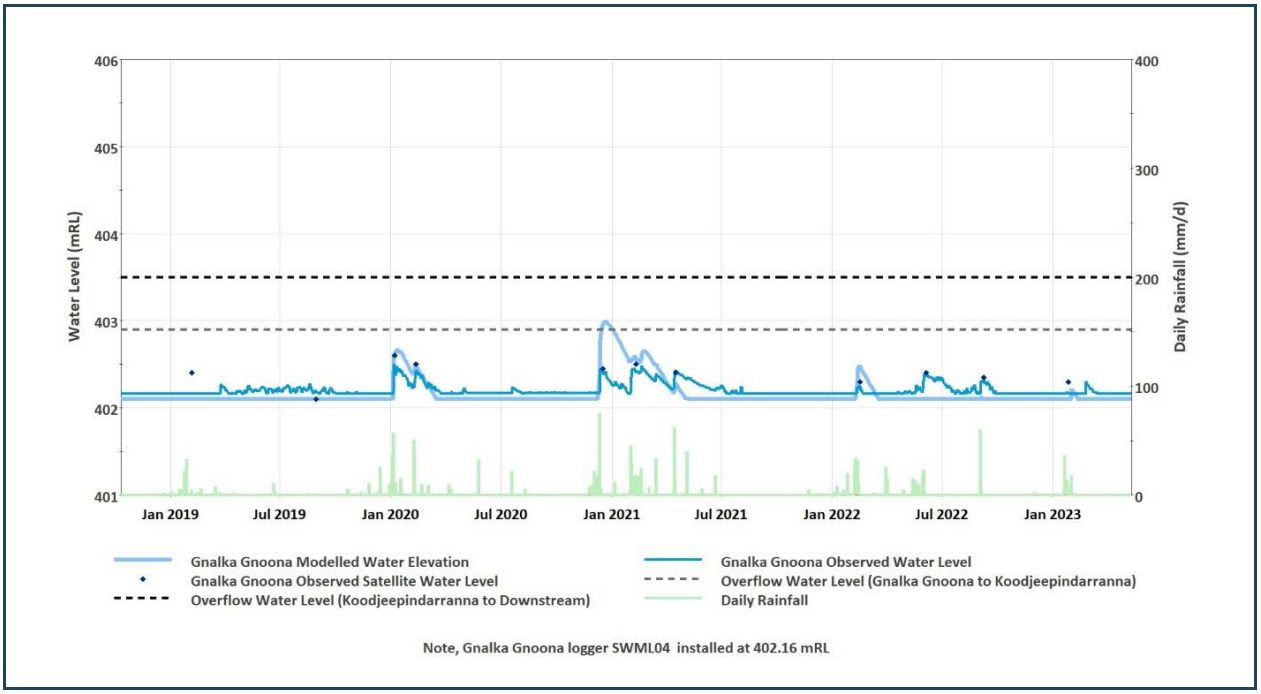


Figure 4.10 Short-Term Calibration – Gnalka Gnoona Claypan Water Levels

As well as the calibration against water levels, TDS concentration predictions from the model were compared against the observed values in the claypan (although the model wasn't calibrated to achieve the salinity results). A comparison of the observed and modelled salinity is shown in Figure 4.11 and Figure 4.12. The following should be noted with respect to the salinity predictions:

- Observed salinity in the claypans is typically below 500 mg/L, with the exception of "first flush" spikes in salinity prior to large inflows of runoff into the claypan.

- The modelled salinity approximates the timing and magnitude of the observed salinity levels reasonably well in both claypans, with the exception of matching the peak values at the end of a ponding event. The reasons for this discrepancy are discussed below.
- Within the GoldSim water/salt balance, the calculated salinity becomes extremely high as the volume of water within the claypan reduces, due to the TDS being calculated by dividing the mass of salt by an increasingly smaller volume. The logic within the model has been programmed to overwrite the salinity to 0 mg/L when the storage volume becomes (nominally) less than 0.1% of the maximum storage volume (to the overflow point) in each of the claypans.
    - Note that TDS concentration is set to 0 mg/L for plotting purposes, however the mass of salt within the claypan is preserved for the next runoff inflow event.
    - The 0.1% volume cut-off was nominally selected to keep the modelling salinity within the same order of magnitude as the observed salinity so that the comparison could be viewed.
    - The 0.1% volume cut-off also generally coincides with the point at which the water level in the claypans falls below the salinity sensor elevation.
- The data logger in the claypans is not located in the lowest point of the claypans. Hence the salinity in the claypans could increase above the values shown below as the lake surface area further reduces.

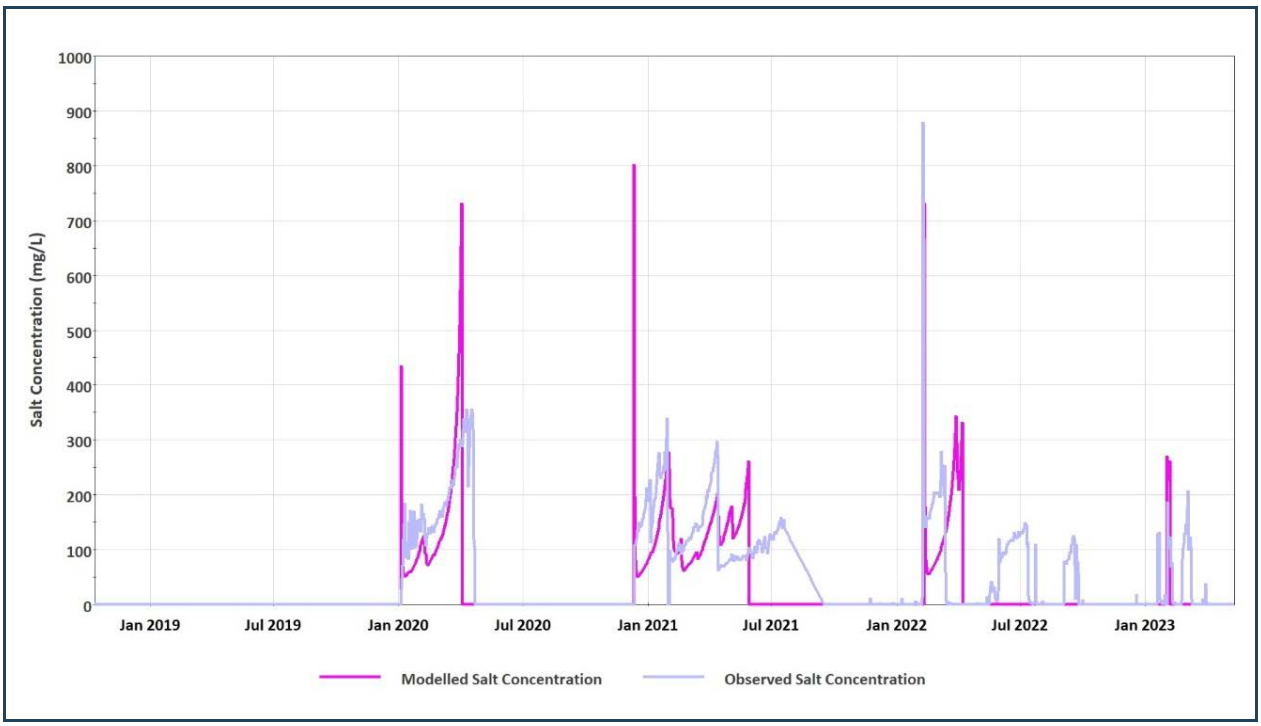


Figure 4.11 Short-Term Calibration – Koodjeepindarranna Claypan Salinity

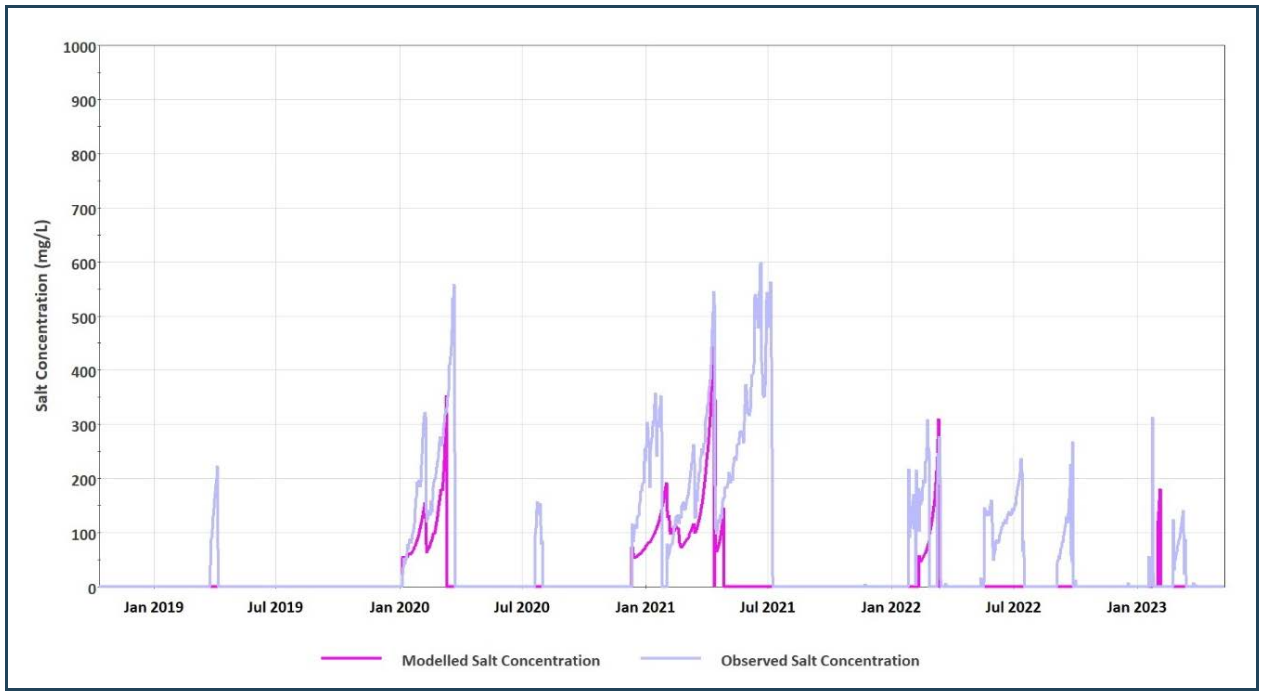


Figure 4.12 Short-Term Calibration – Gnalka Gnoona Claypan Salinity

4.4.5.2 Longer-Term Calibration Run

The Short-Term Calibration model parameters produced model predictions which approximate measured claypan water levels from the baseline data collection period, but the magnitude of rainfall events during this period were relatively small. The model was run for an extended duration (from 1988) to test the loss parameters identified in the short-term calibration exercise during a period which contained larger rainfall events, with model predictions compared to inundation extents from aerial images of the claypans obtained from Sentinel, Landsat and Google Earth satellites. The inundation events are plotted against the model predictions in Figure 4.13 and Figure 4.14.

The water balance assumes the full claypan catchment contributes runoff from the applied excess rainfall depths (after accounting for losses). This may lead to an overestimation of runoff to the claypans as rainfall events are unlikely to occur with the same intensity across the large catchment.

As catchments E and L have the potential to contribute large runoff volumes (refer Table 4.6), it was found varying the ROC in proportion to the size of the rainfall event was required to calibrate the model to predict both the small and large inundation events observed within the claypans. The adopted ROC's and this approach are documented in more detail in Section 4.4.5.1.

There is a varying level of confidence in the estimated inundated extents from observed satellite imagery and whether available imagery coincides with the actual peak inundation extent. The level of confidence is lower for imagery pre-2014 as there is missing imagery for extended periods, some images do not cover the full claypan extents and imagery capture was less frequent.

When comparing the observed inundation depths and the model predictions, the following was noted:

- The water levels observed in the 1988 events may potentially be underestimated due to the infrequent imagery captures from Landsat 4-5 at this time.

- Between 2008 and 2012 small inundation events were observed but not predicted by the water balance. It is possible the baseline rainfall dataset extract throughout this period was less representative of the actual rainfall that fell on the effective claypan catchments or that the IL parameter adopted in the model was lower during this period because of the wetter climate sequence.
- It is likely a large inundation event occurred in early 1999, although it was only sighted within the Fortescue Valley upstream of the Great Northern Highway (and thus not plotted) as aerial imagery of the claypans was missed or obscured by clouds. This would match the water balance model predictions.
- Only limited Google Earth imagery was available between December 1999 to May 2003 and September 2011 to March 2013. This imagery was sparsely taken and overlaid in places by multiple images such that it was difficult to ascertain when images were taken. Notably, there is limited confidence in the 2012 and 2013 wet season as discussed below:
    - The baseline rainfall dataset extract suggests large claypan responses should be prevalent for both years, with the 2013 rainfall event larger than the 2012 rainfall event.
    - Imagery taken approximately 6 months after the 2012 rainfall event appears to show large levels of ponding persisting in the claypan. From the aerial image, the peak water level in the claypan which was likely to have occurred immediately following rainfall was inferred from signs of potential ponding.
    - Imagery in 2013, similarly available 6 months post rainfall event only shows a small amount of remnant ponding in the claypans.
    - The water balance predictions appear to underpredict and overpredict the 2012 and 2013 wet season events respectively, however the water balance results are consistent with the observed rainfall records.

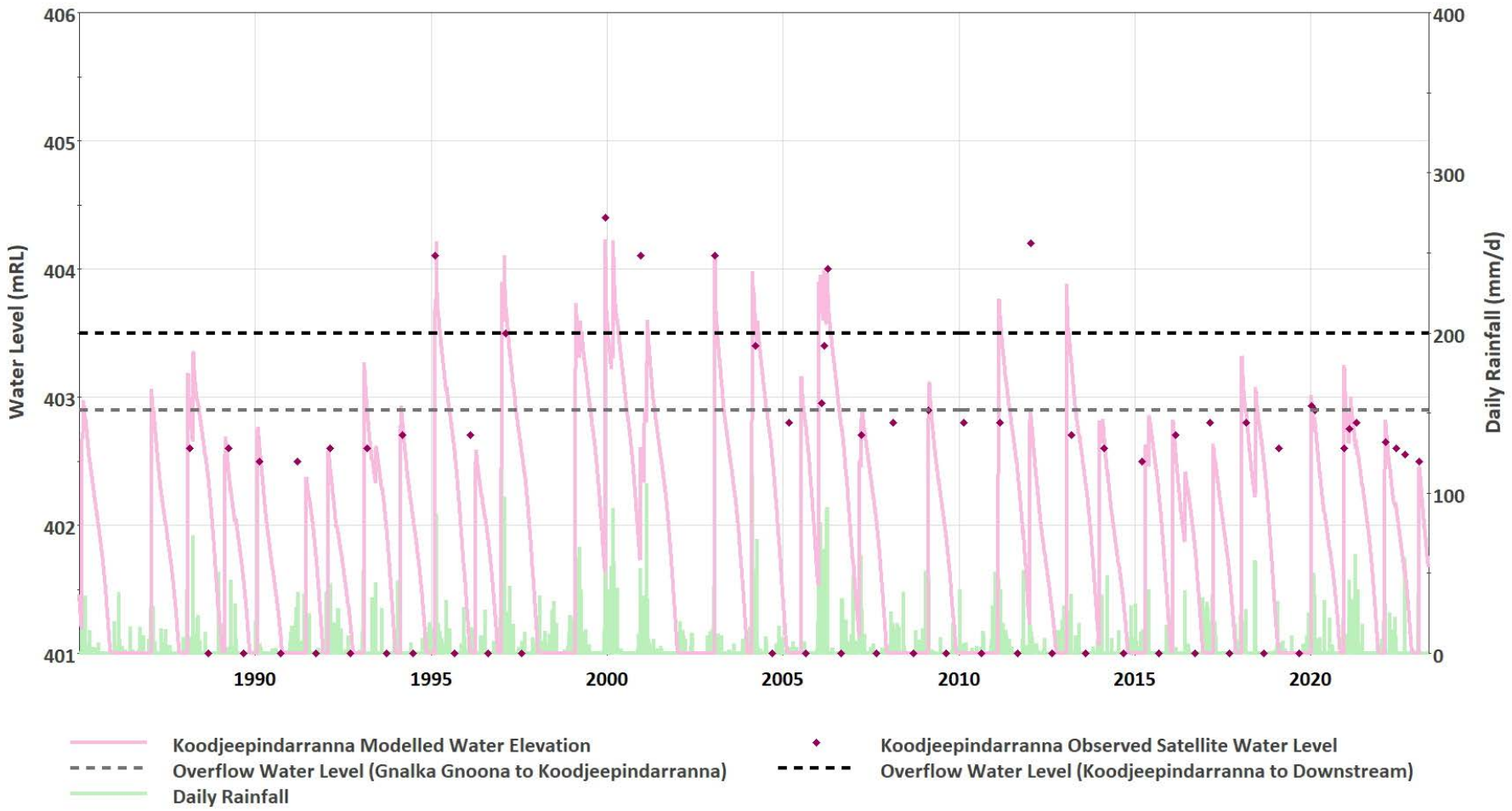


Figure 4.13 Longer-Term Calibration Results – Koodjeepindarranna Claypan

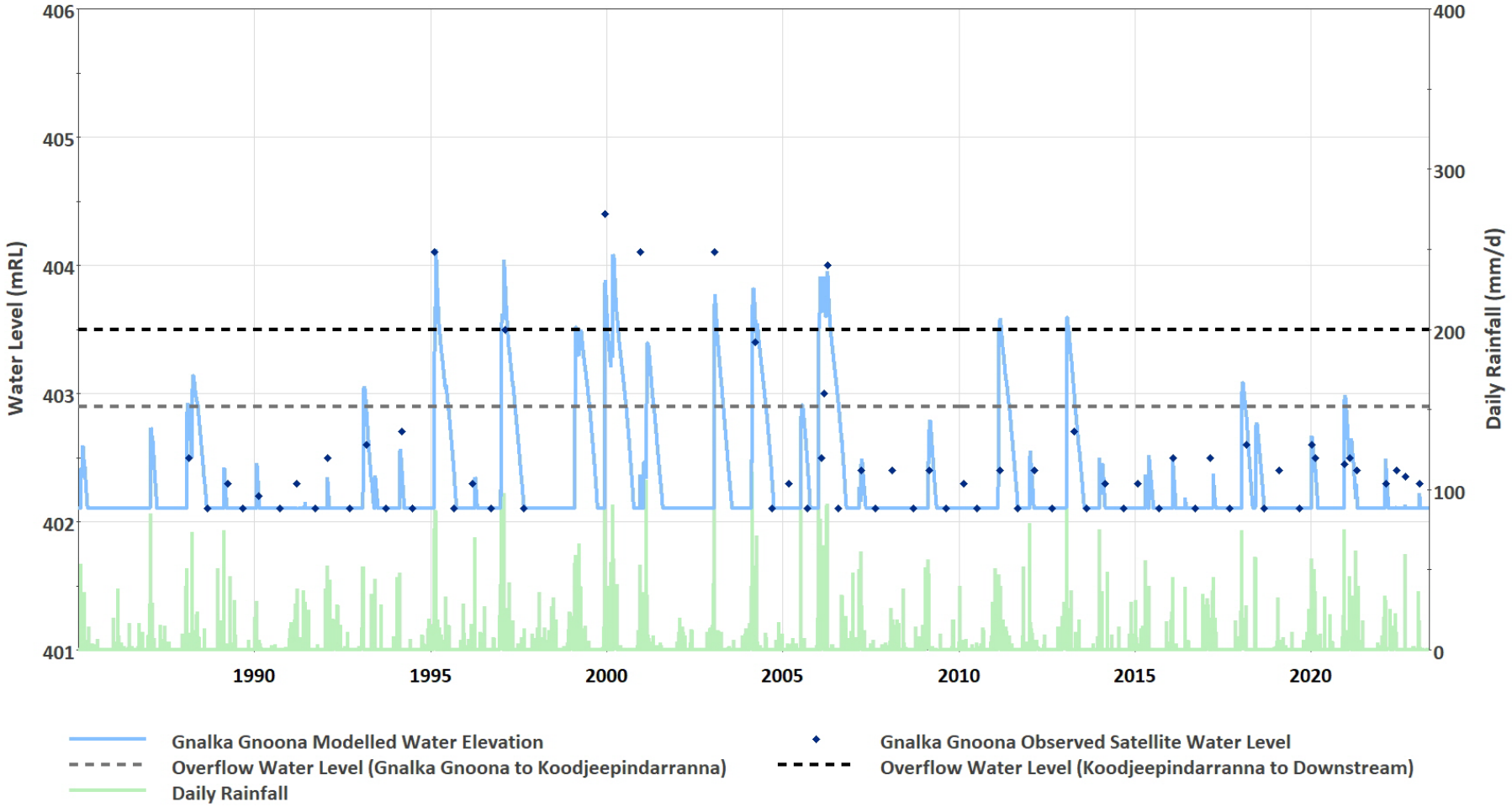


Figure 4.14 Long-Term Calibration Results – Gnalka Gnoona Claypan

4.4.5.3 Calibration Summary

The following observations were made from these results:

- The rainfall loss and seepage loss parameters adopted in the Short-Term Calibration also resulted in the Longer-Term Calibration approximating the observed claypan levels over the longer (satellite based) observation period.
- The long-term calibration run suggests large inundation events in the claypans may occur as a result of large runoff volumes from the Hamersley and/or Chichester Range catchments.
- The rate of overflow from the Koodjeepindarranna claypan downstream impacts the duration of ponding in the claypan and therefore the pond recession curve. To define the outflow rate from Koodjeepindarranna claypan a rating curve developed from the 2D flood model results was used.
- The water depth in the claypans from the base to the downstream overflow elevation is 1.5 m (Gnalka Gnoona) and 2 m (Koodjeepindarranna) in each of the claypans. Comparison with the annual average evaporation depth of 2.4 m, indicates that flooding from a single rainfall event is unlikely to sustain water levels in the claypans for a full year. This is simulated in the water balance model, where surface water ponding typically does not persist for the full year.
- There are differences between the predicted water levels in the claypans and the observed water levels in the satellite imagery, however the model provides a reasonable overall approximation of the observed data. There is inherent uncertainty in the model predictions due to the following main factors:
    - During the period that claypan water levels have been measured (short-term calibration), there has only been relatively small flood events.
    - The model simplifies relatively complicated rainfall-runoff-storage processes to predict claypan responses. Although the rainfall loss parameters within the model have been calibrated to observed claypan water levels, different combinations of loss parameters and different loss models may also have been able to produce results which approximate the observed data.
    - Uncertainty within the definition of the catchment areas which report to the claypans and changes in the effective catchment areas reporting to the claypans depending on the size of the rainfall event. This uncertainty has been reduced by the development of the large-scale baseline flood model, which has allowed flow paths to be identified and the spread of water across the alluvial fans to be predicted.
    - Overflow processes between the claypans and downstream to the Fortescue Valley. Note that these overflow processes have a large impact on what the defined flood level in the claypans would be for different recurrence intervals, such that the defined flood levels of the claypans have a large degree of uncertainty related to them. Again, analysis of the 2D flood model predictions has been used to better estimate the stage vs overflow relationship of the claypans.
    - Uncertainty in the stage-storage-area curve, particularly related to the impact that vegetation may have on the data.
    - Uncertainty in the relative level of the pressure transducer compared to the DEM elevations, and therefore how the observed water depths were converted into observed water levels and storage volumes.
    - How representative the baseline rainfall dataset extract is of the actual rainfall depths which fell over the entire claypan catchment areas.

The objective of the water balance modelling was to provide baseline predictions of the claypans which can be compared to catchment conditions when proposed mine development occurs. Despite the uncertainty in the input parameters, the model provides a reasonable approximation of the hydrological behaviour of the claypans which can be used for this purpose.

A secondary objective of the water balance modelling was to produce an annual maxima series of peak water levels within the claypans for input into a Flood Frequency Analysis (FFA). It should be noted that the limitations within the water balance model simulation also impact the definition of the annual maxima series, and therefore the FFA.

4.4.6 Long-Term Water Balance Predictions

Using the water balance parameters that were defined by the calibration runs, a model was developed for the full duration of the baseline rainfall dataset extract.

The predicted water levels within the claypans are shown on Figure 4.15 and Figure 4.16 and represent the Baseline claypan water level predictions. These results were used to complete a FFA on the predicted claypan flood levels. Some observations from the long-term model include:

- The largest predicted water level in the claypans occurred in the 1974/1975 wet season when 320 mm of rainfall was recorded over 24 hours.
- The 1994/1995 wet season event produced the second largest predicted water level in the claypans.
- Large inundation events were predicted in the claypans between 1995 and 2010 with a greater frequency than other periods of time. As shown in Figure 4.15, the 1995-2010 period was wetter on average, and included a number a large rainfall events, such as:
    - 6 rainfall events exceeding 80 mm of rain in 24 hours, with 3 of these exceeding 160 mm of rainfall.
    - 895 mm of rainfall falling over a 3-month period.
    - 990 mm of rainfall falling over a 6-month period.
- The longest period of continuous claypan inundation predicted to be stored above the elevation of the installed Claypan Surface Water Monitoring Stations (~403.2 mRL) is in the order of 300 days (i.e. the claypan hydroperiod). There were 19 occasions (within the 72-year model duration) where the hydroperiod of the claypans was predicted to exceed 200 days above 403.2 mRL.
- The results indicate that flooding within the claypans can be driven by both a single rare (very large) rainfall event, or by multiple consecutive large rainfall events. Ponding in the claypans would rarely exceed a year's duration.

Other observations from the Baseline claypan water balance model are:

- Claypan water levels are predicted to exceed the overflow linking the two claypans (402.9 mRL), on average, every 2 years.
- Claypan water levels are predicted to exceed the downstream overflow level (403.5 mRL), on average, once every 3-4 years.
- The claypans are predicted to typically dry-out during the dry season in most years.
- The highest claypan water level predicted by the model was 405.4 mRL.

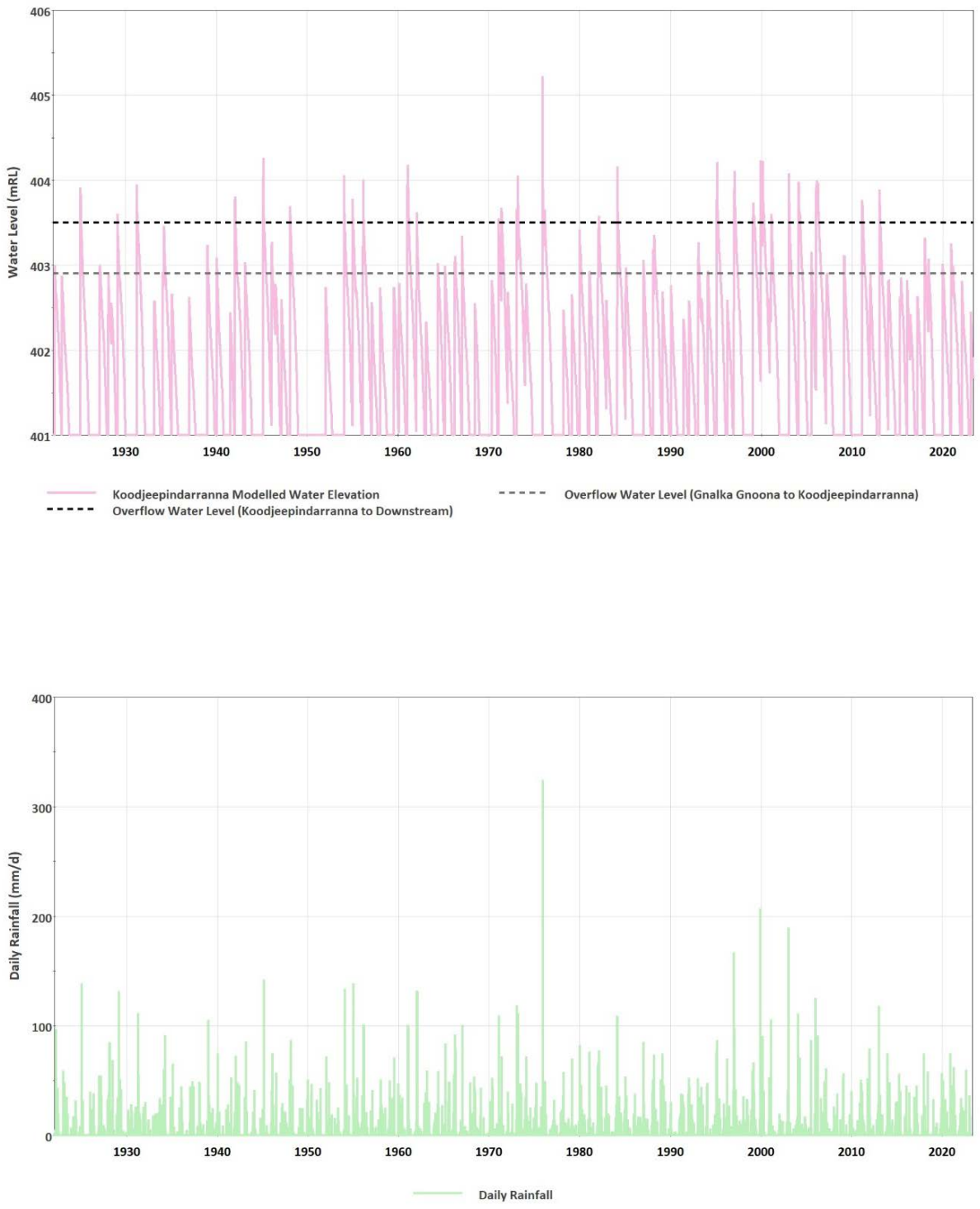


Figure 4.15 Baseline Water Balance Model Predictions – Koodjeepindarranna Claypan

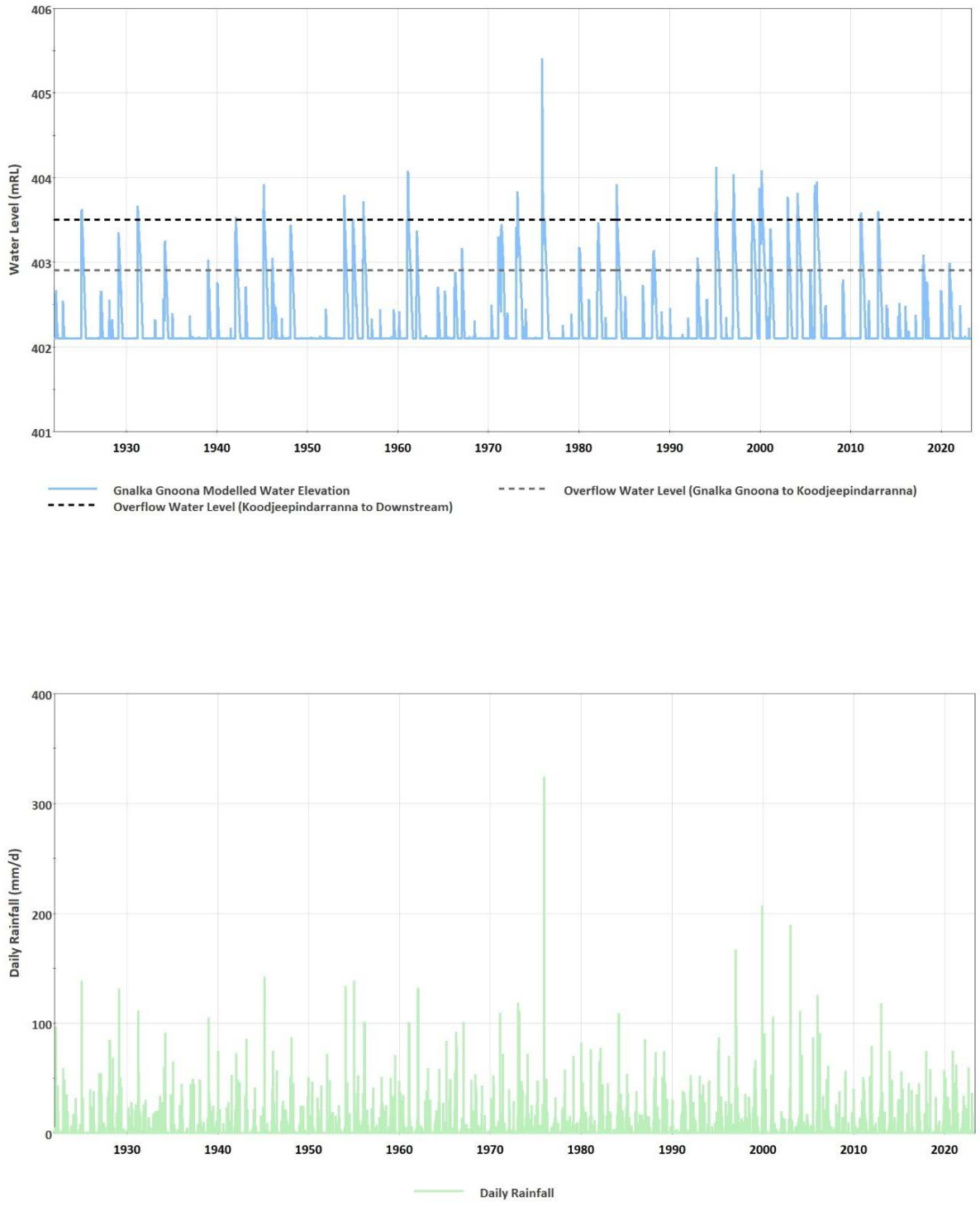


Figure 4.16 Baseline Water Balance Model Predictions – Gnalka Gnoona Claypan

4.4.7 Updated Flood Frequency Analysis

An annual maxima series was developed for the Gnalka Gnoona claypan water levels using the Long-Term Water Balance model predictions discussed in Section 4.4.6. The annual maxima series consisted of 102 years of data and was imported into the software package TUFLOW Flike and a Flood Frequency Analysis (FFA) completed by fitting the series to a number of different probability distributions to determine the flood level for different recurrence interval events.

The annual maxima series was censored to remove years where the model does not predict any ponding of water in the claypan. Comparing the different curves available for fitting the annual maxima series, it was found that the Generalised Pareto was the most appropriate fit for the data. The results of the regression analysis are provided in Table 4.8. It is assumed that the same flood levels are experienced in both claypans.

Table 4.8 FFA Results – Claypan Peak Water Levels

ARI (1 in Y)	% AEP	Peak Water Level (mRL)
5	20	403.4
10	10	403.9
20	5	404.3
50	2	404.8
100	1	405.0

Based on the FFA, the peak water level within the claypan area is estimated to be 405.0mRL for a 1% AEP event. For reference, the largest flood event predicted in the Long-Term Water Balance Model was 405.4mRL (in 1975), which was estimated to be a 1 in 170-year storm event by the FFA.

The limitations within the FFA are mostly related to the limitations in the claypan water balance. However, if the FFA is used to estimate flood rates significantly greater than the 1975 flood event (the largest event in the water balance model), a further limitation is that the FFA does not take into account any physical limitations to the depth of flooding which may occur. In this instance, the stage/volume curve for the claypans and the rate at which water can overflow from the Koodjeepindarranna Claypan at larger inflow rates would not be considered within the FFA.

A plot of the FFA result is shown in Figure 4.17.

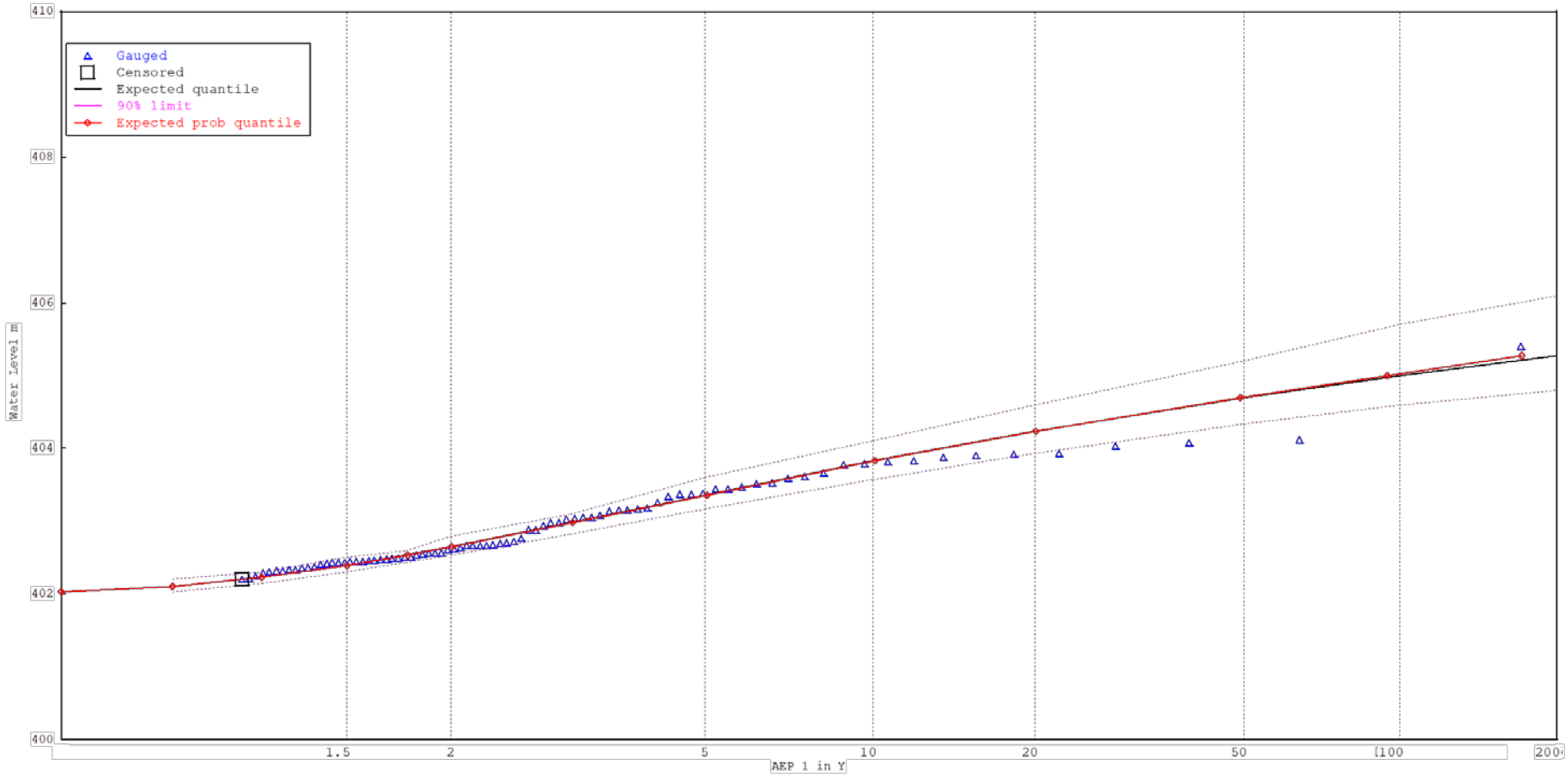


Figure 4.17 Gnalka Gnoona Claypan Flood Depth FFA Result

4.5 Surface Water Quality Measurements

The collected water quality samples provide some baseline water quality data and can be found in Appendix G. The locations of where these samples were collected are shown in Figure 3.4. Given the naturally large variability in the runoff data, additional samples are required to be collected with time to provide a more robust baseline dataset which could be used to characterise the surface water quality for the Project. The water quality within the claypans will also vary with time as the runoff evapo-concentrates.

In general, water quality sample results indicate that surface water runoff within the Study Area is fresh and generally pH neutral. There is the potential that the natural runoff can have high levels of suspended sediment. The salinity in the claypans tends to be fresh immediately following a runoff event, but salinity increases with time as the ponded water evapo-concentrates.

The collected baseline water quality data have been compared with the ANZECC Freshwater Aquatic Ecosystem guideline values to show where the runoff from the existing catchments exceeds them. With reference to the Aquatic Ecosystem Guidelines, note the following:

- Samples collected from the creeks and channel pools are classified as being from an 'Upland River' sub-system for comparison to physical stressor trigger values.
- Samples collected from the claypans would be classified as being from a 'Fresh Water Lakes' sub-system for comparison to physical stressor trigger values.
- The site would be classified as slightly to moderately disturbed due to the historic and continuing cattle farming practices that occur through the catchment. However, the site is considered to have a high conservation value (refer Section 1.7).
- As such, sampled results have been compared against ANZECC Tropical Fresh Water trigger levels for physical stressors for Upland River and Freshwater Lakes ecosystems (refer Appendix G), as well as toxicant trigger values for both ecosystem types associated with 95% species protection.

The water quality analysis results are shown Appendix G, with a summary provided in Table 4.9 of the key parameters which have been analysed. With reference to the tables shown in Appendix G:

- Red cells indicate values where ANZECC 95% Species Trigger Level values have been exceeded.
- Blank cells indicate where samples were not analysis for the associated analyte.
- "<" indicates observed analyte level is below the laboratory detection limit.

The key observations made from the water quality data collected to date are as follows:

- Aluminium, Zinc, Phosphorus, Sulfate concentrations measured are consistently above the trigger levels.
- The measured TDS concentrations of the samples taken from the claypans (SWML03 and SWML04) are variable (as expected) depending on the timing of the sample collection relative to the date of the inundation event.
- In general, claypan samples have a higher conductivity, TDS and alkalinity.

Table 4.9 Summary of Key Baseline Surface Water Quality Results (mg/L)

	Drainage Line Samples		Claypan Samples	
	Range	Typical	Range	Typical
TDS[#]	18 to 240	100	120 to 19,000	~4,000
Calcium	1.6 -21	10	3.9 - 35	5
pH (pH Units)	3.7 - 8	6.4	7 – 8.3	7.2
Bicarbonate	<5 - 47	20	50 - 130	100
Carbonate	<5	<5	<5	<5
Ammonia - N	<0.02 – 9.5	1	<0.02 - 6	1
Nitrate-N	0.02 - 28	2	<0.01 – 1.6	1
Filterable Reactive Phosphorus	<0.01 – 1.8	0.1	<0.01 – 0.44	0.1
Magnesium	0.4 – 5.6	4	1.2 - 180	3
Sulfate	2 – 43	5	<1 to 230	40
Sodium	0.8 – 15	5	22 - 950	40
Chloride	2 – 17	<5	11 – 1,600	50
Aluminium (dissolved)	0.015 – 1.6	0.1	1.8 – 7.4	5
Iron (dissolved)	0.02 – 0.85	0.08	0.06 - 14	8

Notes

Samples from drainage lines in 2019 have not been included in this summary, as these were collected using a different methodology which likely resulted in abnormally high TDS water quality results.

Variable water quality in the claypans reflects evapo-concentration of water stored in the claypans following runoff events.

5. GROUNDWATER FIELD INVESTIGATIONS

5.1 Introduction

Early hydrogeological field investigations at Mulga Downs were undertaken by MWH, with two drilling and testing programmes conducted in 2009 and 2012. Thereafter, AQ2 has undertaken three phases field investigations in (2018/19, 2021 and 2023) and introduced a comprehensive programme of baseline monitoring, commencing in early 2019. As data from each of these programmes has been used to develop the conceptual hydrogeological model, each programme is detailed in the sections below.

All completed bores have been named using the HPPL naming convention, as summarised below:

- Production bores have a prefix "MDPB".
- Monitoring bores (piezometers) have a prefix "MDPZ".
- At paired or cluster monitoring bore sites, the same bore name/number is used with a suffix to indicate the relative depth:
  - For paired bores, "D" for the deep and "S" for shallow.
  - For cluster bores sites, "A" for the deepest, "B" for the next deepest and "C" for the shallowest.

5.2 Preliminary Hydrogeological Investigations

As part of the early hydrogeological investigations undertaken by MWH (2009; 2012; 2014), a number of HPPL mineral exploration bores were retrofitted as monitoring bores. The monitoring bore construction comprised casing these holes with predominantly 25 mm ND PVC casing, with no gravel pack or annular seals. Some of these bores were then equipped with In-Situ Troll water level data loggers. Additionally, several production bores (MDPB001 to MDPB0010) were installed, with pumping tests conducted on selected bores. The locations of these monitoring and production bores are shown in Figure 5.1 with bore and pumping test details tabulated in Appendix C, together with available bore completion logs. Early investigations were predominantly focused on the northern flanks of the valley, within the Mulga East tenement (R47/12). A summary of the reports associated with the previous hydrogeological studies is given below:

- March 2009 – Murray's Hill Groundwater investigation: test pumping and hydrochemistry of MDPB001 (Murray's Bore) and MDPB002 (East Wooley Bore), salinity profiling of MD0173, MD0572, MD0573, MD0574, MD0551 and MDPB002.
- October 2012 – Assessment of Fenceline Borefield Area (Mulga East): test pumping and hydrochemistry of MDPB004, MDPB005 and MDPB006.
- March 2014 – Conceptualisation of Hydrogeology of the Mulga East Deposit, based on existing data for MDPB004, MDPB005 and MDPB006 plus salinity profiles for MDPZ0704, MDPZ0708, MDPZ0745, MDPZ0757.

5.3 AQ2 Field Investigations

Summaries of the three phases of investigations are presented in Sections 5.3.1 to 5.3.3, with further details thereafter.

5.3.1 Baseline Study 2018/2019

AQ2 undertook a baseline study under contract to JBS&G (for HPPL). The objectives of the 2018/2019 hydrogeological field investigations were to:

- Further develop the hydrogeological understanding of the Study Area, particularly to the south of the deposit where previous data were limited and conservation areas associated with ecological communities exist.

- Install a groundwater monitoring network to provide a means of collecting baseline hydrogeological data.
- Collect a hydrogeological data set against which the potential impacts of mining could be identified.

Bore locations were selected following an initial desktop study and conceptualisation process (AQ2 2018); locations were limited to the HPPL tenements and were sited along existing tracks, outside of conservation areas. Production bore locations were identified based on the results of the exploration drilling / monitoring bore installation and the spatial distribution of geological units.

The 2018/2019 hydrogeological drilling and bore construction were undertaken by Ausdrill Northwest (now Pentium Hydro) under direct contract to HPPL, using a Foremost DR24 HD rig. Drilling commenced on 10th November 2018 and was completed on 10th August 2019, with a 6-week break over the Christmas / New Year period, a 1-week hiatus due to weather (Cyclone Veronica) and a ~2-month hiatus (from May to July 2019) awaiting native vegetation clearances.

A total of 51 monitoring bores were installed at 23 locations (MDPZ7449 to MDPZ7471) comprising 8 single monitoring bores and 15 cluster monitoring bores (14 sets of three cluster bores and one deep cluster bore (MDPZ7465A) adjacent to an existing shallow bore (MDPZ0757)). In addition, 5 test production bores (MDPB0011 to MDPB0015) were installed. Locations of the bores installed during the 2018/2019 field programme are presented in Figure 5.2.

Test pumping of the five production bores was conducted between the 3rd September and 9th October 2019 by McArthur Drilling and Pumping Pty Ltd (MDP), under contract to Strategen-JBS&G.

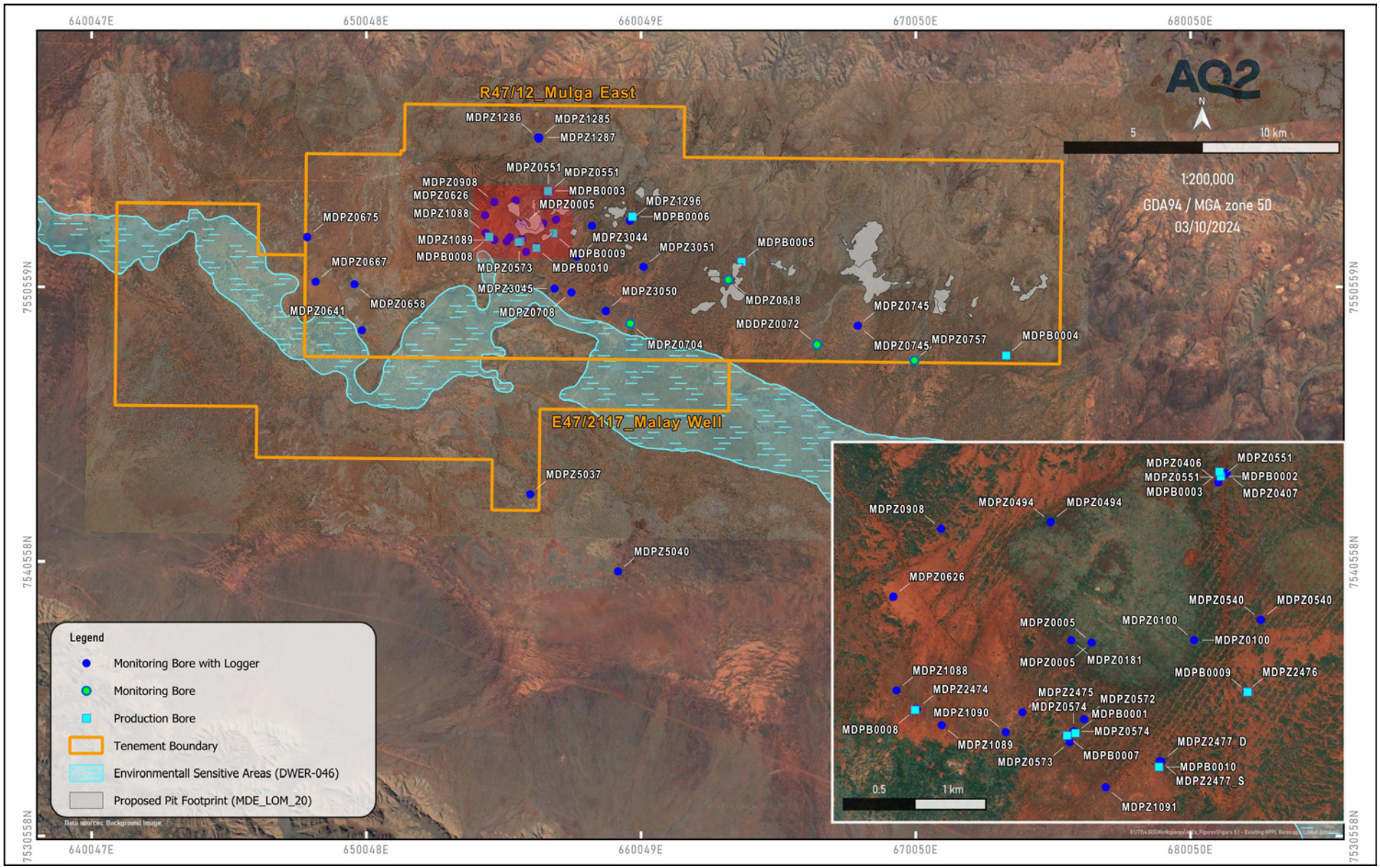


Figure 5.1 Historic Existing HPPL Bore Location

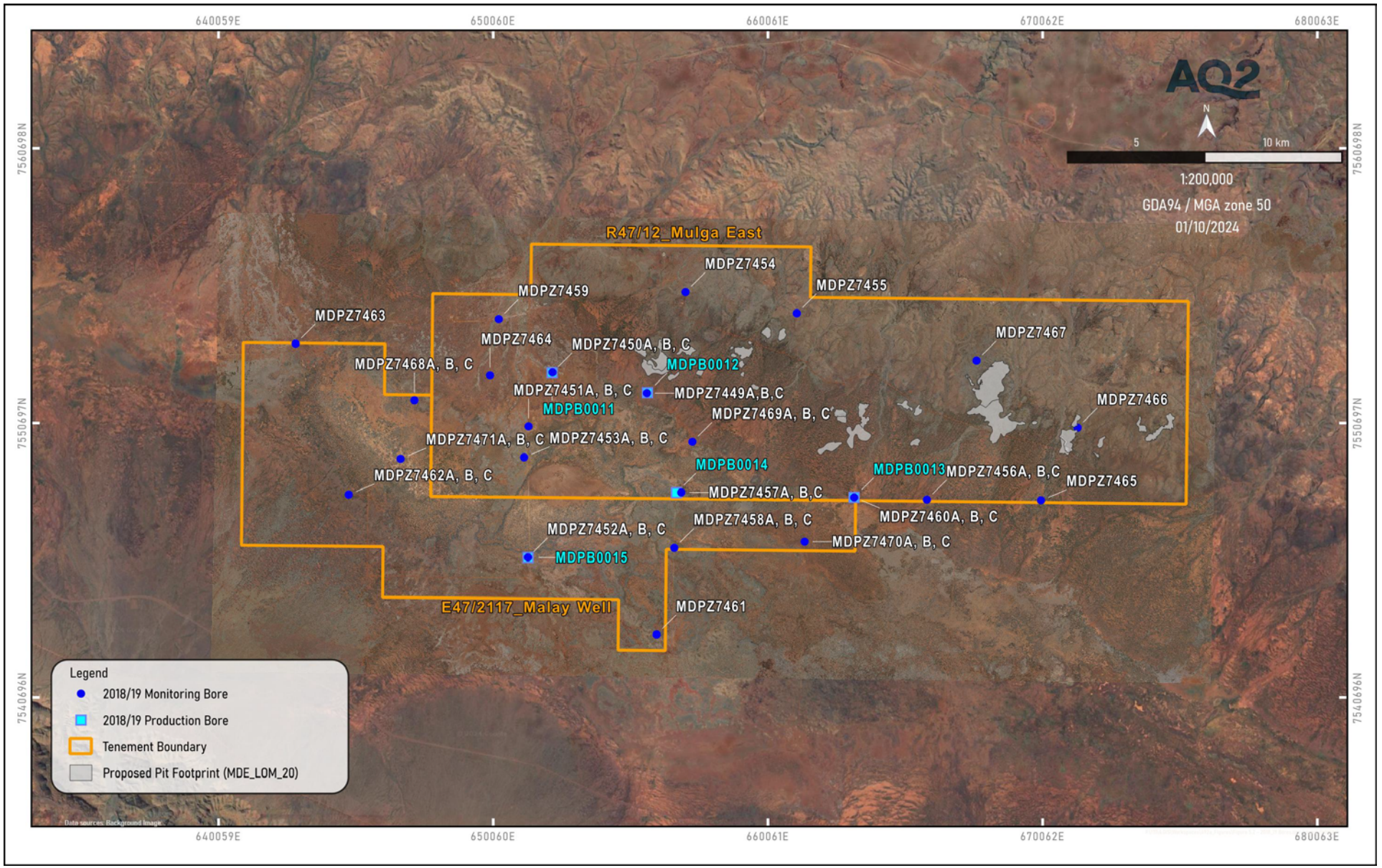


Figure 5.2 2018/2019 Bore Locations

5.3.2 2021 Investigations

The 2021 investigations were undertaken under contract to Roy Hill. The objectives were to address risks associated with mine dewatering, water supply and excess water disposal (through managed aquifer recharge (MAR)), in addition to extending the existing hydrogeological understanding and baseline monitoring network to incorporate the Mulga West tenement area.

Drilling sites were selected as part of a preliminary desktop study (AQ2 2021). Water supply drill sites in the orebody area were restricted to areas of low salinity groundwater, on the assumption that water for processing would need to have a salinity of less than ~5,000 mg/L TDS. Whilst MAR drill sites were in areas where groundwater salinity was anticipated to be higher. Investigations were focused on the disposal of high salinity water as this carries increased risk, i.e. it has more potential to have a detrimental impact on other users and / or the environment. Drill sites were selected based on an assessment of data from existing reverse circulation (RC) drilled mineral holes within the identified areas of interest. All 2021 drill sites were near to an existing RC hole, outside of the identified conservation and heritage areas, with access along existing station / exploration tracks.

Aside from the predetermined locations of the two production bores for dewatering investigations, all other production bore locations were identified based on the observed hydrogeological data from the exploration drilling / monitoring bore installation.

The 2021 drilling and bore construction were undertaken by Pentium Hydro under direct contract to Roy Hill, using a Foremost DR24 HD rig. Drilling commenced on 7th July 2021 and was completed on 13th December 2021.

A total of 23 monitoring bores were installed at 21 locations (MDPZ9201 to MDPZ9221) comprising 14 single unsealed monitoring bores, five single sealed monitoring bores and four paired monitoring bores (two paired bores at two sites). In addition, five test production bores (MDPB0016 to MDPB0020) were installed. The locations of the 2021 bores are shown Figure 5.3 (for the Mulga East and Malay Well tenements) and Figure 5.4 (for the Mulga West tenement).

Hydraulic testing via test pumping of the five production bores and mini testing of six monitoring bores (MDPZ9205, 9206, 9208, 9209, 9210 and 9213) was conducted by MDP, under contract to Roy Hill. This work was conducted in two stages between the 21st September and 21st October 2021 and between 25th November and 18th December 2021.

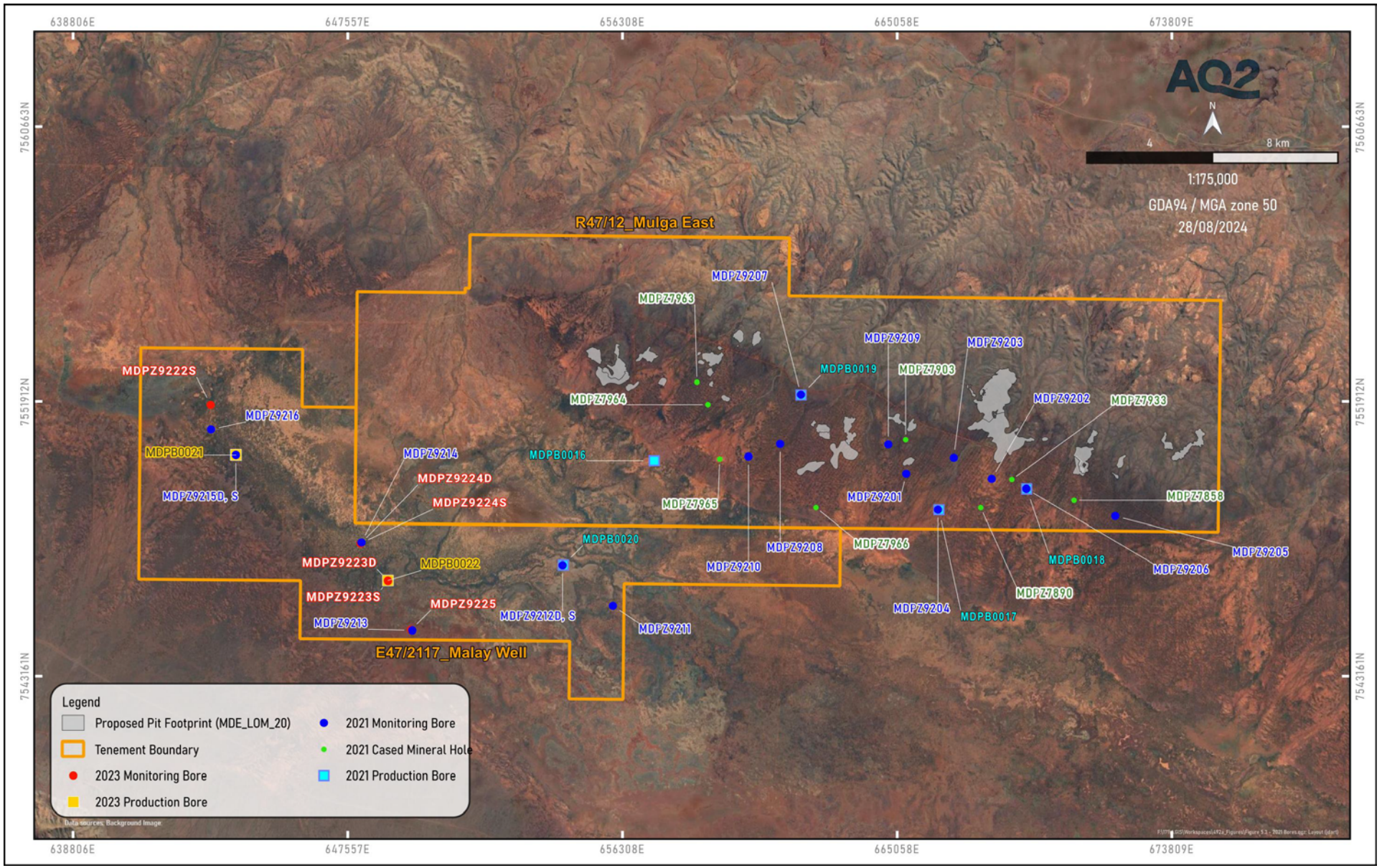


Figure 5.3 2021 and 2023 Bore Locations - Mulga East & Malay Well Tenements

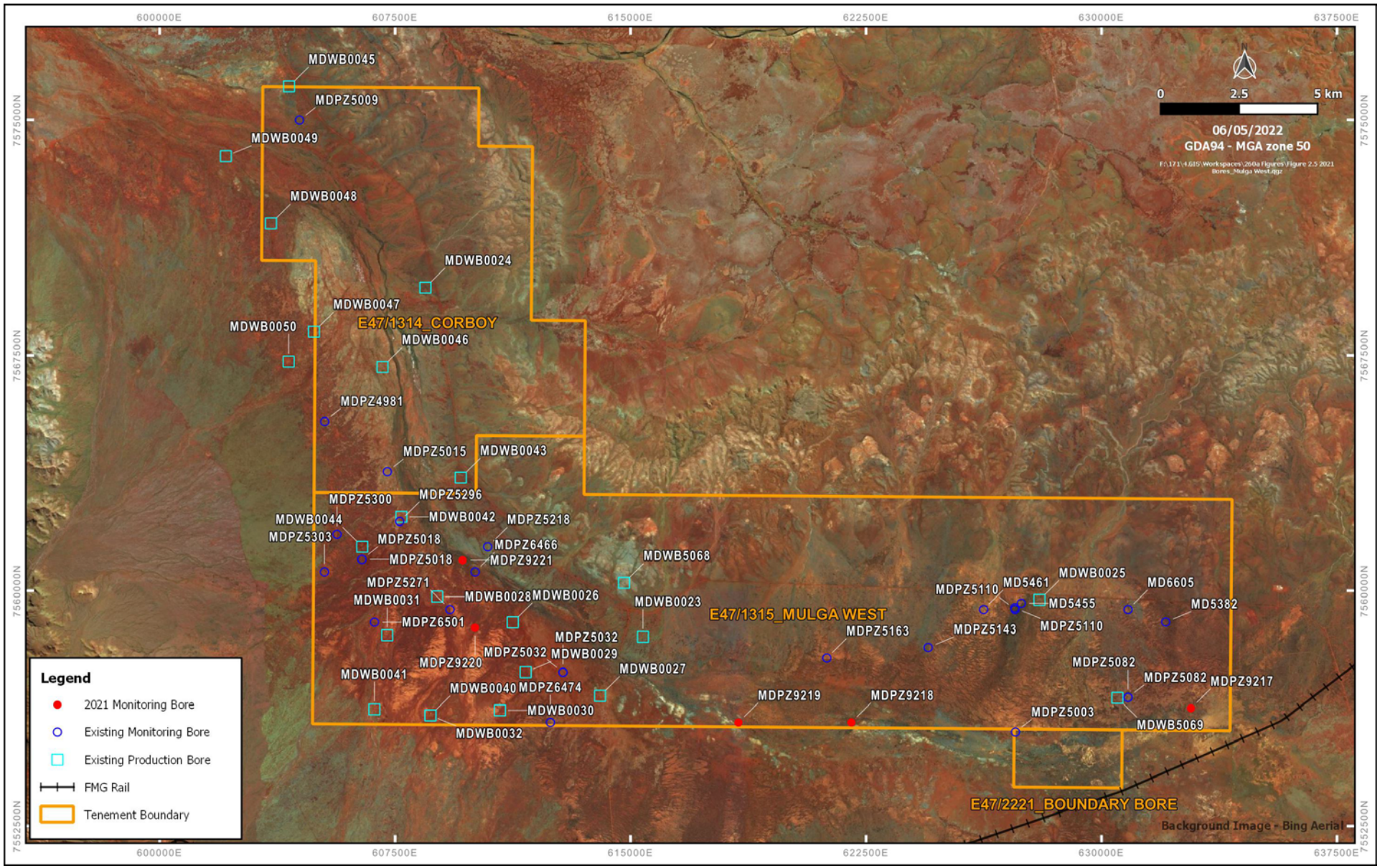


Figure 5.4 2021 Bore Locations – Mulga West

5.3.3 2023 Investigations

The 2023 investigations were undertaken under contract to Roy Hill. The objectives were to install test production / re-injection bores and undertake further hydrogeological exploration over the proposed re-injection area within the Malay Well tenement. However, drilling sites were restricted to existing drill pads as further clearing within Mungurrdu (although not officially registered at the time) was not permitted. In an effort to reduce the detrimental impact on shallow groundwater quality, if the upper 40 to 50 m of groundwater was found to be <10,000 uS/cm EC, the screened intervals of production re-injection bores were installed below 40 m depth (with the upper 40 m grouted off), such that, if used for re-injection purposes, direct injection would only be into the deeper, more saline interval.

The drilling and bore installation were undertaken by Pentium Hydro under contract to Roy Hill between 4th August and 11th October 2023, using a Schramm T130 drill rig.

A total of six monitoring bores were installed at four locations (MDPZ922 to MDPZ9225) comprising two single monitoring bores and four paired monitoring bores (i.e. deep and shallow) at two sites. In addition, two production / re-injection bores (MDPB0021 and MDPB0022) were installed. The locations of these bores are shown in Figure 5.3.

Although test pumping / re-injection trials were proposed, this work has been deferred, initially due to wet season access restrictions and subsequently due to the requirement for further approvals for work within Mungurrdu.

5.3.4 Drilling and Bore Construction

Between 2018 and 2023 a total of 80 monitoring bores and 12 test production bores have been installed across the Mulga East, Malay Well and Mulga West tenements. Drilling was undertaken using dual-rotary (DR) techniques through unconsolidated ground and conventional down-the-hole hammer (DTH) techniques through competent bedrock. Bore locations are presented in Figure 5.4 and Figure 5.5, with the drilling and bore installation methodology summarised below. Monitoring bore details are presented in Table 5.2 to Table 5.3, with production bore details in Table 5.4. Hydrogeological / bore completion logs for all bores are provided in Appendix D.

Monitoring Bores

The monitoring bores were drilled at 9" (DR) and 7.5" (DTH) diameters, with all DR (conductor) casing retrieved during bore completion. At each paired or clustered bore location, the deepest bore was installed first, such that the lithology / hydrostratigraphic units could be identified and the target units / bore completion designs determined. One hole in 2021 (MDPZ9207(L)) was declared lost at 46 m due to a break in the conductor casing string; the hole was subsequently redrilled to total depth on the same pad. Whilst in 2023, at hole MDPZ9222, the drill rods snagged on the DR casing when pulling out of the hole, such that the DR casing had to be retrieved with the rods, before bore completion. Due to the subsequent collapse of the hole, only a shallow bore completion could be achieved.

For all holes, drill cuttings were collected at 2 m intervals and logged by the site hydrogeologist. Airlift yields were recorded at the end of each rod during drilling, together with measurements of EC, pH and temperature for the discharge water.

The 2018/19 monitoring bores (MDPZ7449 to MDPZ7471) were completed with 50 mm ND Class 18 PVC casing, with 2 mm machine-slotted casing installed against the targeted aquifer unit; the 2 mm slot size was used for the purposes of stygofauna monitoring. The first four 2021 monitoring bores (MDPZ9201 to MDPZ9204) were completed with Class 12, 50mm ND bell-end PVC (1 mm slots), thereafter all subsequent monitoring bores (MDPZ9205 to MDPZ9225) were completed with Class 18, 100 mm ND threaded PVC (1 mm slots).

For all monitoring bores, the annulus was packed with graded gravel (3.2-6.4 mm) to 2 m (in 2018/19) to 6 m (in 2021 and 2023) above the slotted section, above which a bentonite seal was placed, with the remaining annulus (above the seal) backfilled with a cement grout. All monitoring bores were airlift-developed for between one and two hours, until the discharged water was free from sediment. Discharge rates during airlifting were measured and water samples collected for chemical analysis. Bore headworks comprised a heavy-duty steel standpipe with lockable cap and a small concrete surface plinth.

Production Bores

The 2018/19 and 2021 production bores were drilled at 16" (DR) and 14.5" (DTH) diameters, while the 2023 production / test reinjection bores were drilled at ~18" (DR) and 16.5" (DTH). All DR casing was retrieved during production bore completion. Bore MDPB0020 could not be drilled to the targeted depth, despite the mobilisation of an auxiliary compressor, due to excessive yields (~140 L/s).

As for the monitoring bores, drill cuttings were collected at 2 m intervals and logged by the site hydrogeologist. Airlift yields were recorded at the end of each rod during drilling, together with measurements of EC, pH and temperature for the discharge water.

Production bores MDPB0011 to MDPB0019 were completed with 250 mm ND Class 12 PVC, with 1 mm slotted casing. Bore MDPB0020, in the Malay Well MAR investigation area, was completed with 250 mm ND, Class 18 PVC blank casing, with 250 mm ND wire-wound stainless-steel screens (1 mm slot) whilst subsequent test re-injection bores in the Malay Well MAR investigation area (MDPB0021 and MDPB0022) were completed with 300 mm ND, Class 18 PVC blank casing, with 300 mm ND wire-wound stainless-steel screens (1 mm slot). As shallow groundwater at MDPB0021 and MDPB0022 was found to be <10,000 uS/cm EC, the screened intervals were installed below 40 m depth (with the upper 40 m grouted off), such that, if used for re-injection purposes, direct injection would only be into the deeper, more saline interval.

The annulus of all production bores was packed with graded gravel (3.2–6.4 mm). Bores MDPB0016 to MDPB0019 were gravel packed to 2 mbgl, above which a bentonite 'surface seal' was placed. All other production bores were gravel packed to 2 m (in 2018/19) to 6 m (in 2021 and 2023) above the slotted section, above which a bentonite seal was placed, with the remaining annulus (above the seal) backfilled with cement grout.

All production bores were airlift-developed for between 4 and 12 hours, until the discharged water was free from sediment. Discharge rates during airlifting were measured and water samples collected for chemical analysis. Bore headworks comprised a heavy-duty steel standpipe with lockable cap and a concrete surface plinth.

Discharge

To avoid environmental harm (as required under the *Environmental Protection Act 1986*), drilling-discharge during each field investigation campaign was contained in line with the requirements at that time. For the 2018/19 investigations, DWER advised that all drilling-discharge water exceeding 10,000 µS/cm required containment; whilst in 2021 all water exceeding 7,300 µS/cm EC required containment, as per Roy Hill's Water Discharge Management Procedure. In 2023, in line with the requirements of the Banjima People, for working with in Mungurrdu (although not officially registered at that time), all discharge water was contained in sumps.

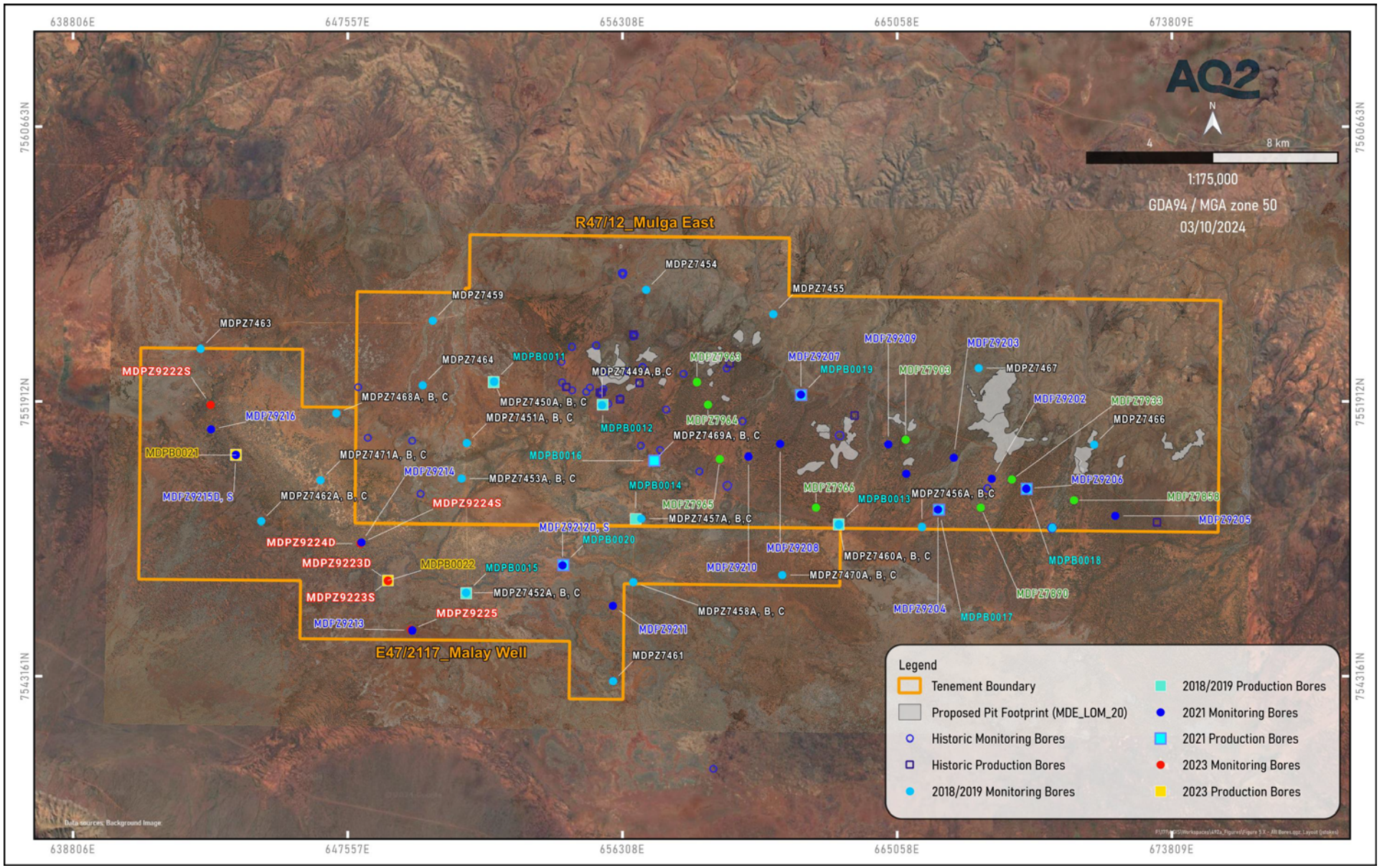


Figure 5.5 2018 to 2023 Bore Locations – Mulga East & Malay Well

Table 5.1 2018/9 Monitoring Bore Details

Hole ID	Easting MGA_50	Northing MGA_50	Top of Casing (mRL)	Stick-up (m)	Drilling Method	Drill Depth (mbgl)	Drill Diam (mm)	Max Drilled Airlift (L/s)	Cased Depth (mbgl)	Casing	Casing ND (mm)	Screened Depth (m)	Unit Monitored	Completed	SWL (mbTOC)	SWL (mRL)	Date of SWL
MDPZ7449A	655656.40	7551784.82	405.93	0.54	DR / DTH	0-52 / 52-82	241/191	15	82	CL18 PVC	50	52-82	Marra Mamba	14/11/2018	4.92	401.01	8/09/2019
MDPZ7449B	655656.95	7551794.50	405.99	0.56	DR / DTH	0-46 / 46-52	241/191	15	47	CL18 PVC	50	11-47	CID/Pisolite	16/11/2018	5.25	400.74	8/09/2019
MDPZ7449C	655656.84	7551804.66	405.98	0.54	DR	0-11	241	0.1	10.65	CL18 PVC	50	4.65-10.65	Upper Silcrete (+ Pisolititic Clay)	17/11/2018	5.25	400.73	8/09/2019
MDPZ7450A	652212.74	7552518.04	406.86	0.59	DR / DTH	0-52 / 52-102	241/191	35	102	CL18 PVC	50	48-102	Marra Mamba	20/11/2018	6.43	400.43	8/09/2019
MDPZ7450B	652202.67	7552512.35	406.69	0.61	DR / DTH	0-40 / 40-42	241/191	5	42	CL18 PVC	50	22-42	CID/Pisolite	22/11/2018	6.33	400.36	8/09/2019
MDPZ7450C	652197.73	7552504.43	406.77	0.58	DR	0-22	241	5	22	CL18 PVC	50	10-22	Undiff. Tertiary	23/11/2018	6.36	400.41	8/09/2019
MDPZ7451A	651328.49	7550564.57	404.46	0.53	DR / DTH	0-118/118-120	241/191	25	120	CL18 PVC	50	94-120	Marra Mamba	27/11/2018	5.37	399.09	8/09/2019
MDPZ7451B	651335.19	7550574.10	404.58	0.54	DR	0-64	241	10	62	CL18 PVC	50	52-62	Basal Calcrete	1/12/2018	5.21	399.37	8/09/2019
MDPZ7451C	651343.79	7550577.11	404.54	0.53	DR / DTH	0-40/40-44	241/191	5	44	CL18 PVC	50	14-44	Undiff. Tertiary	3/12/2018	4.87	399.67	8/09/2019
MDPZ7452A	651326.77	7545805.52	404.45	0.60	DR / DTH	0-58 / 58-72	241/191	45	72	CL18 PVC	50	53-72	Basal Calcite & Dolomite	5/12/2018	4.29	400.16	26/02/2019
MDPZ7452B	651336.38	7545806.11	404.35	0.61	DR	0-53	241	30	51.5	CL18 PVC	50	32.5-51.5	Undiff. Tertiary	7/12/2018	4.24	400.11	26/02/2019
MDPZ7452C	651345.87	7545807.09	404.44	0.60	DR / DTH	0-28/28-32	241/191	7	32	CL18 PVC	50	8-32	Upper Calcrete	8/12/2018	4.35	400.09	26/02/2019
MDPZ7453A	651179.71	7549447.05	405.44	0.47	DR / DTH	0-64 / 64-72.5	241/191	25	72.5	CL18 PVC	50	52.5-72.5	Basal Calcrete	11/12/2018	6.38	399.06	8/09/2019
MDPZ7453B	651188.93	7549447.07	405.42	0.49	DR / DTH	0-46 / 46-48	241/191	22	48	CL18 PVC	50	30-48	CID/Pisolite & Undiff. Tertiary	12/12/2018	6.24	399.18	8/09/2019
MDPZ7453C	651198.83	7549447.51	405.30	0.49	DR	0-17	241	5	17	CL18 PVC	50	9-17	Upper Calcrete	13/12/2018	6.13	399.17	8/09/2019
MDPZ7454	657054.03	7555455.52	436.49	0.57	DR / DTH	0-4/4-58	241/191	0.3	58	CL18 PVC	50	16-58	Jeerinah	29/01/2019	26.62	409.87	8/09/2019
MDPZ7455	661107.77	7554688.42	448.71	0.59	DR / DTH	0-4/4-61.5	241/191	1.25	60	CL18 PVC	50	14-60	Jeerinah	1/02/2019	31.63	417.08	8/09/2019
MDPZ7456A	665850.76	7547906.10	410.67	0.49	DR / DTH	0-52/52-120.5	241/191	20	120	CL18 PVC	50	62-120	Marra Mamba (lower)	8/02/2019	8.33	402.34	8/09/2019
MDPZ7456B	665865.23	7547917.74	410.77	0.55	DR / DTH	0-52/52-62	241/191	20	62	CL18 PVC	50	46-62	Marra Mamba (upper)	3/02/2019	8.44	402.33	8/09/2019
MDPZ7456C	665858.43	7547912.29	410.72	0.53	DR / DTH	0-40/40-42	241/191	10	41	CL18 PVC	50	6-41	CID/Pisolite & Undiff. Tertiary	4/02/2019	8.44	402.28	8/09/2019
MDPZ7457A	656707.00	7548167.60	405.02	0.55	DR / DTH	0-70/70-100	241/191	20	100	CL18 PVC	50	76-100	Marra Mamba (incl Hardcap)	11/02/2019	4.79	400.23	8/09/2019

Hole ID	Easting MGA_50	Northing MGA_50	Top of Casing (mRL)	Stick-up (m)	Drilling Method	Drill Depth (mbgl)	Drill Diam (mm)	Max Drilled Airlift (L/s)	Cased Depth (mbgl)	Casing	Casing ND (mm)	Screened Depth (m)	Unit Monitored	Completed	SWL (mbTOC)	SWL (mRL)	Date of SWL
MDPZ7457B	656716.47	7548166.77	405.07	0.54	DR	0-59	241	20	59	CL18 PVC	50	41-59	CID/Pisolite & Basal Calcrete	12/02/2019	4.71	400.36	8/09/2019
MDPZ7457C	656725.70	7548165.99	405.14	0.57	DR	0-35	241	14	35	CL18 PVC	50	19-35	Upper Calcrete	13/02/2019	4.73	400.41	8/09/2019
MDPZ7458A	656645.81	7546145.78	404.73	0.58	DR	0-71	241	30	71	CL18 PVC	50	54-71	CID/Pisolite, Basal Calcrete, Dolomite	18/02/2019	4.33	400.40	8/09/2019
MDPZ7458B	656655.16	7546145.38	404.81	0.56	DR	0-52	241	20	52	CL18 PVC	50	45-52	CID/Pisolites	20/02/2019	4.40	400.41	8/09/2019
MDPZ7458C	656664.79	7546144.68	404.88	0.63	DR	0-41	241	20	41	CL18 PVC	50	5-41	Upper Calcrete	25/02/2019	4.44	400.44	8/09/2019
MDPZ7459	650261.72	7554484.42	410.73	0.54	DR	0-28	241	3.5	28	CL18 PVC	50	5-28	Alluvial Fan Gravel (Undiff Tert)	27/02/2019	11.21	399.52	7/09/2019
MDPZ7460A	663200.83	7547990.12	406.66	0.46	DR / DTH	0-58 / 58-112	241/191	25	112	CL18 PVC	50	70-112	Marra Mamba	3/03/2019	5.02	401.64	8/09/2019
MDPZ7460B	663194.31	7547981.81	406.67	0.52	DR	0-53.4	241	8.5	53.4	CL18 PVC	50	45.4-51.4	CID/Pisolite	5/03/2019	5.21	401.46	8/09/2019
MDPZ7460C	663189.48	7547975.65	406.74	0.65	DR	0-29.3	241	3.7	29.3	CL18 PVC	50	17.3-29.3	Undiff Tertiary	6/03/2019	5.33	401.41	8/09/2019
MDPZ7461	656011.19	7542996.40	405.74	0.47	DR / DTH	0-54 / 54-119.2	241/191	15	119.2	CL18 PVC	50	5.2-119.2	Upper Calcrete/CID/Basal Calcite/Dolomite	9/03/2019	4.88	400.86	10/03/2019
MDPZ7462A	644800.00	7548090.09	404.41	0.58	DR / DTH	0-58 / 58-120	241/191	12.5	120	CL18 PVC	50	63-120	Basal Silcrete / Dolomite	17/03/2019	4.96	399.45	7/09/2019
MDPZ7462B	644799.50	7548099.81	404.46	0.52	DR	0-58.5	241	12	58.5	CL18 PVC	50	39.5-58.5	CID/Pisolite & Undiff Tertiary	21/03/2019	5.11	399.35	7/09/2019
MDPZ7462C	644798.52	7548109.80	404.50	0.58	DR	0-35	241	12.2	35	CL18 PVC	50	21-35	Upper Calcrete	22/03/2019	5.25	399.25	7/09/2019
MDPZ7463	642862.56	7553586.81	404.37	0.28	DR / DTH	0-82 / 82-88	241/191	35	85.5	CL18 PVC	50	10.5-85.5	Upper Calcrete/Undiff Tertiary/CID/Basal Calcrete/Wittenoom	1/04/2019	5.64	398.73	7/09/2019
MDPZ7464	649944.40	7552426.04	406.18	0.28	DR	0-88	241	25	88	CL18 PVC	50	6-88	Upper Calcrete/Undiff Tertiary/CID/Marra Mamba	6/04/2019	6.75	399.43	7/09/2019
MDPZ7465A	670002.47	7547874.81	418.86	0.52	DR	0-112	241	>20	111.5	CL18 PVC	50	87.5-111.5	Marra Mamba	9/04/2019	15.67	403.19	8/09/2019
MDPZ7466	671335.89	7550527.64	438.95	0.55	DR / DTH	0-4 /4-64.9	241/191	4.8	64.8	CL18 PVC	50	34.8-64.8	Marra Mamba	12/04/2019	34.66	404.29	8/09/2019

Hole ID	Easting MGA_50	Northing MGA_50	Top of Casing (mRL)	Stick-up (m)	Drilling Method	Drill Depth (mbgl)	Drill Diam (mm)	Max Drilled Airlift (L/s)	Cased Depth (mbgl)	Casing	Casing ND (mm)	Screened Depth (m)	Unit Monitored	Completed	SWL (mbTOC)	SWL (mRL)	Date of SWL
MDPZ7467	667654.85	7552968.50	449.78	0.46	DR / DTH	0-4 /4-64	241/191	3.5	64	CL18 PVC	50	34-64	Marra Mamba (& Jeerinah?)	14/04/2019	43.45	406.33	8/09/2019
MDPZ7468A	647192.36	7551560.72	403.60	0.51	DR / DTH	0-82 / 82-89	241/191	25	89	CL18 PVC	50	68-89	Marra Mamba	17/04/2019	4.98	398.62	7/09/2019
MDPZ7468B	647195.75	7551569.71	403.68	0.58	DR	0-65	241	15.2	65	CL18 PVC	50	56-62	Basal Calcrete / Silcrete	19/04/2019	5.02	398.66	7/09/2019
MDPZ7468C	647199.39	7551578.68	403.74	0.62	DR	0-52	241	11.2	52	CL18 PVC	50	21.3-51	CID/Pisolite & Undiff Tertiary	20/04/2019	5.11	398.63	7/09/2019
MDPZ7469A	657312.11	7550018.04	404.31	0.50	DR / DTH	0-88/88-101	241/191	>25	101	CL18 PVC	50	93-101	Marra Mamba	25/04/2019	4.01	400.30	8/09/2019
MDPZ7469B	657307.53	7550026.67	404.25	0.37	DR	0-83	241	18	82	CL18 PVC	50	64-82	Marra Mamba (Hydrated Hardcap)	27/04/2019	3.45	400.80	8/09/2019
MDPZ7469C	657303.02	7550034.90	404.24	0.53	DR	0-53	241	4.3	52.5	CL18 PVC	50	10.5-52.5	Undiff Tertiary	29/04/2019	3.49	400.75	8/09/2019
MDPZ7470A	661397.44	7546376.66	405.64	0.89	DR / DTH	0-58 / 58-108	241	>30	104	CL18 PVC	50	74-104	Mt Newman / West Angela?	22/07/2019	4.51	401.13	9/08/2019
MDPZ7470B	661388.05	7546376.16	405.82	0.96	DR / DTH	0-46 / 46-49	241	10	49.1	CL18 PVC	50	29.1-49.1	Undiff Tertiary	24/07/2019	4.62	401.20	9/08/2019
MDPZ7470C	661378.85	7546375.58	405.80	0.95	DR	0-23	241	6	23	CL18 PVC	50	11-23	Upper Calcrete	24/07/2019	4.56	401.24	9/08/2019
MDPZ7471A	646670.59	7549390.44	403.60	0.90	DR / DTH	0-58 / 58-78	241	43	78	CL18 PVC	50	68-78	Mt Newman / West Angela?	28/07/2019	4.51	399.09	7/09/2019
MDPZ7471B	646660.88	7549391.41	403.78	1.10	DR / DTH	0-52 / 52-60	241	16	60	CL18 PVC	50	30-60	Undiff Tertiary / Pisolite / Basal Calcrete	29/07/2019	4.65	399.13	7/09/2019
MDPZ7471C	646680.73	7549389.40	403.57	0.93	DR	0-21	241	4.4	21	CL18 PVC	50	11-21	Upper Calcrete	31/9/2019	4.79	398.78	7/09/2019
MDPZ5355	654392.26	7546201.78	404.77	0.71	RC	0-118	150		28	CL18 PVC	50	4-28*	Whole sequence	16/05/2019	4.66	400.11	8/09/2019
MDPZ5360	648007.66	7546597.47	403.59	0.40	RC	0-100	150		58	CL18 PVC	50	4-58*	Whole sequence	21/05/2019	blocked	-	-
MDPZ5362	646402.111	7548201.139	-	-	RC	0-118	150		114	CL18 PVC	50	0-114*	Whole sequence	23/05/2019	-	-	-

*Alternating blank and slotted casing

Table 5.2 2021 Monitoring Bore Details

Hole ID	Area	Easting MGA94_50	Northing MGA94_50	Top of Casing (mRL)	Stick-up (m)	Drilling Method	Drill Depth (mbgl)	Drill Diam (mm)	Max Drilling Airlift Yield (L/s)	Cased Depth (mbgl)	Casing	Casing ND (mm)	Screened Interval (m)	Bentonite seal (m)	Completed	SWL (mbTOC)	SWL (mRL)	Date of SWL	Final Airlift EC (µS/cm)	Final Airlift pH
MDPZ9201	Mulga E	665349	7549601	414.90	0.46	DR	0-84	230	28	82.5	PVC CL12	50	18-82.5	-	9/07/2021	12.85	402.05	10/08/2021	1,840	7.89
MDPZ9202	Mulga E	668073	7549439	421.70	0.24	DR	0-88	230	18	88.0	PVC CL12	50	16-88	-	13/07/2021	19.42	402.28	13/07/2021	1,140	7.44
MDPZ9203	Mulga E	666865	7550118	421.40	0.57	DR	0-76	230	14	76.0	PVC CL12	50	16-76	-	16/07/2021	19.24	402.16	10/08/2021	1,086	8.15
MDPZ9204	Mulga E	666361	7548461	413.77	0.48	DR / DTH	0-94 94-100	230 190	19	100.0	PVC CL12	50	16-100	-	20/07/2021	11.73	402.04	10/08/2021	2,690	7.69
MDPZ9205	Mulga E	672010	7548259	419.03	0.53	DR / DTH	0-34 34-70	230 190	10	70.0	PVC CL18	100	16-70	-	24/07/2021	15.76	403.27	10/08/2021	1,603	7.79
MDPZ9206	Mulga E	669177	7549127	421.66	0.50	DR	0-89	230	16	89.0	PVC CL18	100	65-89	57-59	28/07/2021	18.60	403.06	10/08/2021	1,629	6.68
MDPZ9207(L)	Mulga E	661985	7552122	426.90	0.55	DR	0-46	230	8	-	-	-	-	-	30/07/2021	-	-	-	-	-
MDPZ9207	Mulga E	661988	7552119	423.71	0.55	DR	0-77	230	14	76.5	PVC CL18	100	16.5-76.5	-	3/08/2021	22.57	401.14	7/08/2021	913	7.51
MDPZ9208	Mulga E	661329	7550554	412.60	0.50	DR / DTH	0-64 64/75	230 190	16.3	74.0	PVC CL18	100	45-74	35.7-38	7/08/2021	11.85	400.75	10/08/2021	1,438	7.57
MDPZ9209	Mulga E	664776	7550535	419.51	0.42	DR / DTH	0-47 47-70	230 190	8.3	70.0	PVC CL18	100	28-70	19.7-21.7	11/08/2021	17.63	401.88	12/08/2021	473	7.55
MDPZ9210	Mulga E	660323	7550147	410.73	0.45	DR / DTH	0-64 64-82	230 190	35	80.0	PVC CL18	100	50-80	42-44	14/08/2021	9.46	401.27	16/08/2021	3,710	7.73
MDPZ9211	Malay	656000	7545396	404.28	0.40	DR / DTH	0-82 82-130	230 190	31	130.0	PVC CL18	100	34-130	-	17/09/2021	3.89	400.39	23/09/2021	16,000	7.19
MDPZ9212D	Malay	654400	7546689	405.62	0.45	DR / DTH	0-100 100-120	230 190	60	118.5	PVC CL18	100	100.5-118.5	94-96	24/09/2021	5.64	399.98	10/11/2021	18,600	7.68
MDPZ9212S	Malay	654386	7546688	405.39	0.44	DR	0-59	230	31	59.0	PVCL18	100	5-59	-	1/11/2021	5.24	400.15	10/11/2021	15,000	7.72
MDPZ9213	Malay	649610	7544612	404.98	0.45	DR / DTH	0-58 58-120.5	230 190	38.5	120.5	PVC CL18	100	18.5-120.5	-	1/10/2021	5.03	399.95	10/11/2021	3,730	7.77
MDPZ9214	Malay	647989	7547414	403.47	0.45	DR	0-125.5	230	21.5	123.7	PVC CL18	100	3.7-123.7	-	10/10/2021	4.03	399.44	12/10/2021	6,010	7.82
MDPZ9215D	Malay	643992	7550206	403.59	0.38	DR	0-130	230	47	130.0	PVC CL18	100	70-130	61.5-64	18/10/2021	4.74	398.85	17/10/2021	22,200	7.43
MDPZ9215S	Malay	643992	7550192	403.61	0.47	DR	0-59	230	12	59.0	PVCL18	100	5-59	-	27/10/2021	4.47	399.14	29/10/2021	4,460	7.74

Hole ID	Area	Easting MGA94_50	Northing MGA94_50	Top of Casing (mRL)	Stick-up (m)	Drilling Method	Drill Depth (mbgl)	Drill Diam (mm)	Max Drilling Airlift Yield (L/s)	Cased Depth (mbgl)	Casing	Casing ND (mm)	Screened Interval (m)	Bentonite seal (m)	Completed	SWL (mbTOC)	SWL (mRL)	Date of SWL	Final Airlift EC (µS/cm)	Final Airlift pH
MDPZ9216	Malay	643199	7551012	403.66	0.42	DR / DTH	0-118 118-119.5	230 190	34	119.5	PVC CL18	100	83.5-119.5	73-75	24/10/2021	5.24	398.42	12/12/2021	21,200	7.21
MDPZ9217	Mulga W	632854	7556252	402.51	0.42	DR / DTH	0-58 58-88	230 190	21.5	89.0	PVCL18	100	5-89	-	20/22/2021	4.78	397.73	21/11/2021	11,400	7.57
MDPZ9218	Mulga W	622035	7555800	399.25	0.40	DR / DTH	0-82 82-92	230 190	27	92.0	PVCL18	100	8-92	-	26/11/2021	3.43	395.82	12/12/2021	8,460	7.66
MDPZ9219	Mulga W	618440	7555798	397.28	0.46	DR / DTH	0-100 100-112	230 190	27.5	112.0	PVCL18	100	10-112	-	30/11/2021	3.69	393.59	5/12/2021	4,180	7.91
MDPZ9220	Mulga W	610046	7558820	395.35	0.37	DR / DTH	0-64 64-94.5	230 190	21.5	94.5	PVCL18	100	10.5-94.5	-	6/12/2021	6.32	389.03	12/12/2021	3,070	7.61
MDPZ9221	Mulga W	609649	7560972	390.34	0.49	DR / DTH	0-70 70-83	230 190	19	83.0	PVCL18	100	11-83	-	12/12/2021	2.50	387.84	13/12/2021	4,240	7.81

Table 5.3 2023 Monitoring Bore Details

Hole ID	Easting MGA_50	Northing MGA_50	Top of Casing (mRL)	Stick-up (m)	Drilling Method	Drill Depth (mbgl)	Drill Diam (mm)	Max Drilling Airlift Yield (L/s)	Cased Depth (mbgl)	Casing	Casing ND (mm)	Screened Depth (m)	Bentonite seal (m)	Completed	SWL (mbrp)	Date of SWL	Completion Airlift Yield (L/s)	Final Airlift EC (uS/cm)	Final Airlift pH
MDPZ9222S	643,187	7,551,797	TBC*	0.60	DR DTH	0-106 106-117	241 191	>40	40	CL18 PVC	100	10-40	75.5-77.5 40-41 0-2	17/08/2023	5.41	28/08/2023	4	18,360	7.93
MDPZ9223D	648,835	7,546,202	TBC*	0.53	DR DTH	0-82 82-94	241 191	42	92	CL18 PVC	100	68-92	61.5-63.5	29/09/2023	5.65	29/09/2023	10 to 20	9,900	-
MDPZ9223S	648,838	7,546,180	TBC*	0.57	DR DTH	0-29 29-30	241 191	7	30	CL18 PVC	100	9-30	0-2	14/10/23	5.65	16/10/2023	6	3,160	7.80
MDPZ9224D	647,965	7,547,379	TBC*	0.37	DR	0-89	241	28	87	CL18 PVC	100	75-87	68-70	31/10/23	4.51	31/10/2023	10	9,040	7.60
MDPZ9224S	647,970	7,547,389	TBC*	0.40	DR DTH	0-52 52-52.5	241 191	14	52	CL18 PVC	100	28-52	20-22	20/10/2023	4.53	31/10/2023	6	4,700	8.05
MDPZ9225	649,571	7,544,628	TBC*	0.56	DR	0-61.3	241	15-20	61.3	CL18 PVC	100	57.3-61.3	52-54	11/05/2023	5.52	13/11/2023	2-3	2,900	8.35

*Not surveyed as yet.

Table 5.4 2018 to 2023 Production Bore Details

Hole ID	Area	Easting MGA94_50	Northing MGA94_50	Top of Casing (mRL)	Stick-up (m)	Drilling Method	Drill Depth (mbgl)	Drill Diam (mm)	Max Drilling Airlift Yield (L/s)	Cased Depth (mbgl)	Casing	Casing ND (mm)	Screened Interval (m)	Screened Unit	Started	Completed	SWL (mbTOC)	SWL (mRL)	Date of SWL	Completion Airlift Yield (L/s)	Final Airlift EC (uS/cm)	Final Airlift pH
MDPB0011	Mulga E	652202	7552525	406.24	0.41	DR	0-23.5	406	2.9	23.5	CL12PVC	250	11.5 - 23.5	U Calcrete Undiff Tert	3/05/2019	6/05/2019	6.19	400.05	8/09/2019	3.8	810	8.39
MDPB0012	Mulga E	655667	7551805	405.51	0.35	DR	0-46.5	406	15	46.5	CL12PVC	250	10.5 - 46.5	Pisolite/ Hardcap	6/05/2019	9/05/2019	5.06	400.45	8/09/2019	15.0	1,503	8.12
MDPB0013	Mulga E	656694	7548124	405.07	0.37	DR DTH	0-57 57-112	406 375	20.7	112	CL12PVC	250	66-112	Marra Mamba	12/05/2019	17/05/2019	4.88	400.19	8/09/2019	10.3	4,770	8.01
MDPB0014	Mulga E	651169	7549452	405.18	0.38	DR	0-35	406	12	35	CL12PVC	250	5-35	Upper Calcrete	18/05/2019	20/05/2019	4.58	400.60	8/09/2019	8.0	5,670	8.52
MDPB0015	Malay	651327	7545797	404.08		DR	0-52	406	50	52	CL12PVC	250	34-52	Undiff Tert Pisolite	5/08/2019	9/08/2019	4.61	399.47	3/09/2019	30.0	6,550	-
MDPB0016	Mulga E	657318	7550024	404.32	0.48	DR	0-88	432	27.5	88.0	PVC CL12	250	10-88	Tertiary & , MM	16/08/2021	24/08/2021	3.25	401.07	25/08/2021	40	2,900	8.01
MDPB0017	Mulga E	666388	7548453	413.79	0.46	DR / DTH	0-88 88-100	432 368	60	100.0	PVC CL12	250	16-100	Tertiary & , MM	25/08/2021	29/08/2021	11.75	402.04	2/09/2021	45	2,850	7.79
MDPB0018	Mulga E	669188	7549120	421.50	0.41	DR / DTH	0-88 88-91	432 368	42	91.0	PVC CL12	250	13-91	Tertiary & , MM	30/08/2021	4/09/2021	18.50	403.00	8/09/2021	38	1,230	7.15
MDPB0019	Mulga E	661995	7552117	423.70	0.54	DR / DTH	0-58 58-77	432 368	24.4	77.0	PVC CL12	250	17-77	Tertiary & , MM	6/09/2021	10/09/2021	22.59	401.11	15/09/2021	10	864	7.9
MDPB0020	Malay	654415	7546689	405.73	0.39	DR / DTH	0-106 106-112.5	432 368	~140	112.5	SS Screen / PVC CL18	250	70.5-112.5	Hardcap, West Ang	2/11/2021	13/11/2021	5.66	400.07	18/11/2021	50	17,100	7.74
MDPB0021	Malay	643,992*	7,550,206*	TBC*	0.44	DR DTH	0-100 100-125	479 419	80	124	CL18 PVC & SS	300	47-71 112-124	Tertiary, Hardcap & West Ang	18/08/2023	20/09/2023	5.20	TBC*	23/09/2023	40	16,970	7.35
MDPB0022	Malay	648,819*	7,546,180*	TBC*	0.65	DR DTH	0-76 76-82	479 419	82	81	CL18 PVC & SS	300	49-79	Tertiary, Hardcap & Wittm Fm dolomite	30/09/2023	10/10/2023	5.55	TBC*	16/10/2023	62	8,860	8.00

*Not surveyed as yet.
MM = Marra Mamba Formation
West Ang = West Angelas Member
Wittm Fm = Wittenoom Formation

5.3.5 Hydraulic Testing

Hydraulic testing was undertaken at the majority of the bores installed in 2018/2019 and all bores installed in 2021. Testing comprised pumping tests on the 10 production bores (MDPB0011 to MDPB0020) and falling head tests, mini-pumping tests, micro-pumping tests and/or airlift recovery tests at the monitoring bores. As with the drilling, the discharge water from the hydraulic testing was either contained within sumps or discharged to the environment, dependent on the salinity of the pumped water. Testing of the bores installed in 2023 has not yet been undertaken. Although pumping tests / re-injection trials were proposed, this work was deferred, initially due to wet season access restrictions and subsequently due to the requirement for further approvals for work within Mungurrdu.

At production bores MDPB0011 to MDPB0019, a step rate test (comprising four sixty-minute steps) and a two to five-day constant rate test were conducted, each followed by a monitored recovery period. Water levels at the tested production bore and adjacent monitoring bore(s) were recorded both manually and with pressure transducers, with the salinity of the discharge water also recorded. All discharge water was transferred via lay-flat to approved discharge locations at distances ranging between 200 and 1,750 m from the tested production bores to minimise re-circulation.

The pumping test at MDPB0016 was conducted to assess a potential change in salinity with time (i.e. dependent on the duration of the test pumping); therefore, the constant rate test at this bore had to be repeated due to pump failure during the first attempt. Salinity profiling of MDPB0016 and the adjacent monitoring bores was undertaken before and after the testing.

Due to the salinity of the groundwater at MDPB0020, the discharge water for this bore required containment; however, it was evident during the drilling of this bore that the adjacent sump leaked, and the discharge water was being re-circulated. The discharge water from the pumping test of MDPB0020 was transferred, via lay-flat, to the sump adjacent to MDPZ9211 (~3 km via existing tracks). The increased discharge distance reduced the maximum potential yield from the pump and, due to the minimal drawdown associated with the maximum pumping rate, it was determined that conducting a step rate test was a low priority. Although a short step rate test (using the sump adjacent to MDPB0020) was proposed after the completion of the two-day constant rate test, this did not eventuate due to rain (and associated access issues) causing an early end to the pumping test programme.

Details of the production bore pumping tests are presented in Table 5.5, with the data plots presented in Appendix E.

The mini- and micro-pumping tests involved the installation of a small, low-yielding pump, together with a pressure transducer to monitor the water level response to pumping. The bores were pumped for 30 to 60 minutes, with monitoring of water levels throughout the test and for one hour after the test (or until water levels had recovered to 90% of the initial drawdown; whichever was the shorter duration). Mini testing was conducted in the 100 mm cased monitoring bores by MDP; whilst micro-pumping was conducted by the site hydrogeologist using a 12V pump on the 50 mm cased monitoring bores. Not all monitoring bores were tested by mini-and micro-pumping, as sufficient drawdown could only be achieved on the lower yielding bores. In addition, bores MDPZ7454, 7455, 7466 and 7467 could not be micro-tested due to the depth to water at these bores being beyond the pumping capacity of pumps that can fit inside 50 mm ND monitoring bores. As such, falling head tests were instead conducted at these bores.

Each falling head test comprised measuring the aquifer response to a near instantaneous change of water level, achieved by adding approximately 80 litres of water into the bore. A pressure transducer was used to measure the water level rise and fall, following the introduction of the water into the bore.

Airlift recovery tests were undertaken at nine of the higher yielding 2018/2019 monitoring bores as well as MDPZ9215D and MDPZ9216D to induce a greater drawdown than that achieved from the mini- and micro-testing. The bores were airlifted for one hour using a poly pipe and drill rig compressor, with an installed pressure transducer / logger recording the water level drawdown and subsequent recovery at two second intervals.

The results of all hydraulic testing were analysed using standard curve-fitting analysis methods; analyses plots are presented in Appendix F.

Table 5.5 Pumping Test Details

Bore	SWL (mbRP)	Step Test			Constant Rate Test								
		Test Date	Step Duration (mins)	Step Discharge Rates (L/s)	Test Start Date	Test Finish Date	Duration	Rate (L/s)	Max Drawdown (m)	EC Range (µS/cm)	Monitoring Bore	Distance from PB (m)	Max Drawdown (m)
MDPB0011	6.19	11/9/19	60	2, 4, 6, 8	12/9/19	17/9/19	120 hrs (5 days)	7	7.49	891-940	MDPZ7450A	13	0.06
											MDPZ7450B	12	0.4
											MDPZ7450C	20	1.39
MDPB0012	5.08	18/9/19	60	10, 20, 30, 37	19/9/19	24/9/19	120 hrs (5 days)	30	16.97	1649-1777	MDPZ7449A	23	0.06
											MDPZ7449B	14	1.27
											MDPZ7449C	10	0.34
											MDPZ1091	182	0.26
MDPB0013	4.88	25/9/19	60	10, 15, 20, 25	26/9/19	1/10/19	120 hrs (5 days)	25	56.78	4860-5790	MDPZ7640A	10	10.18
											MDPZ7640B	10	0.09
											MDPZ7640C	10	0.07
MDPB0014	4.62	3/10/19	60	10, 14, 18, 22	4/10/19	9/10/19	120 hrs (5 days)	22	6.22	5760-6190	MDPZ7457A	20	0.05
											MDPZ7457B	12	0.45
											MDPZ7457C	10	1.75
MDPB0015	4.61	3/9/19	60	10, 20, 30, 40	4/9/19	9/9/19	120 hrs (5 days)	40	10.03	7030-7700	MDPZ7452A	5	1.22
											MDPZ7452B	10	1.68
											MDPZ7452C	15	0.8
MDPB0016	4.28	16/10/2021	60	10, 20, 30, 40	27/11/2021	30/11/2021	75 hrs (3.1 days)	40	7.2	3400-3500	MDPZ7469A	8	0.2
											MDPZ7469B	11	3.6
											MDPZ7469C	18	1.2

Bore	SWL (mbRP)	Step Test			Constant Rate Test								
		Test Date	Step Duration (mins)	Step Discharge Rates (L/s)	Test Start Date	Test Finish Date	Duration	Rate (L/s)	Max Drawdown (m)	EC Range (µS/cm)	Monitoring Bore	Distance from PB (m)	Max Drawdown (m)
MDPB0017	12.66	10/10/2021	60	13, 23, 33, 43	11/10/2021	13/10/2021	52 hrs (2.2 days)	40	1.31	3040 - 3240	MDPZ29204	29	0.44
											MBPZ7456A	767	0.10
											MBPZ7456C	749	0.11
											MBPZ7456B	757	0.13
MDPB0018	19.54	24/09/2021	100	10, 20, 30, 40	25/09/2021	30/09/2021	120 hrs (5 days)	38	4.07	700-1060	MDPZ9206	12	1.42
											MDPZ7933	559	1.2
MDPB0019	23.63	1/10/2021	60	10, 20, 30, 40	4/10/2021	8/10/2021	102 hrs (4.25 days)	38	5.66	740 - 800	MDPZ9207	8	2.7
MDPB0020	6.70	N/A			5/12/2021	6/12/2021	48 hrs (2 days)	20	0.28	17600-18800	MDPZ9212D	15	0.18
											MDPZ9212S	29	0.09
											MDPZ5355	488	0.02

5.3.6 Water Quality Measurements

During all drilling, pH and EC readings of the discharge water were taken at the end of each rod. In addition, a water sample was collected from each completed bore either at the end of airlift development or the end of micro-testing. All collected water samples were analysed by a NATA accredited laboratory (ARL Australia in 2018/2019 and SGS Australia Pty Ltd in 2021 and 2023) for major cations, anions and basic water quality parameters (including pH, EC, total dissolved solids, total hardness and total alkalinity). Hydrochemistry data from the laboratory analyses are tabulated in Appendix G.

Water samples were also collected from the production bores during the constant rate tests. In general, samples for analysis were taken just prior to the completion of the constant rate test. However, for bores MDPB0016 and MDPB0020, samples taken at the commencement of the constant rate test were used for analysis as the test at MDPB0016 finished unexpectedly (due to pump failure) and MDPB0020 could not be accessed following a rainfall event.

5.3.7 Salinity Profiles

Salinity profiles were measured at each completed monitoring bore approximately a week after drilling to allow the water column in the bore to recover, and prior to any hydraulic testing. The process comprised slowly running a Solinst LTC logger or AquaTROLL 200 logger down the bore, by hand, with the logger set at the lowest time-increment.

Salinity profiles for each of the bores are presented in Appendix H, together with the salinity measurements taken during drilling and laboratory salinity data.

5.3.8 Survey Data

Bores installed during the 2018/2019 drilling were surveyed using a Leica Viva GS15 RTK GPS with a horizontal accuracy of 0.1 m and vertical accuracy of +/- 0.05 m. Survey work was conducted by McMullen Nolan Group P/L (MNG) under direct contract to HPPL.

Bores installed in 2021 were surveyed using a Trimble R8S Base - R8 Rover GPS with a horizontal accuracy of 0.05 m and vertical accuracy of +/- 0.05 m. This survey work was conducted by Survey Group under direct contract to HPPL.

To date, none of the 2023 Malay Well bores have been surveyed due to Mungurrdu having restricted access.

5.3.9 Down-hole Survey Data

Down-hole gamma logs were run at each of the 2018/2019 monitoring bores to assist with geological (stratigraphic) logging. These surveys were conducted by Wireline Services Group under direct contact to HPPL. Due to the dimensions of the probe and minor bends in the 50 mm ND bore casing, the probe could not reach total depth for many of the bores. Additionally, the diameter of the drilled hole, together with the annulus fill (i.e. gavel pack / bentonite seal / grout) affected the gamma response.

5.4 Baseline Groundwater Monitoring

During the preliminary hydrogeological investigations (in 2009, 2012 and 2014), selected bores had been equipped with In-Situ Troll transducers / loggers. During the 2018/2019 field programme, these loggers were retrieved, and their status assessed. Data was downloaded from those that were still operational and four selected bores (MDPZ0704, MDPZ0818, MDPZ0757 and MDPZ0072) were re-equipped with loggers.

At the completion of the 2018/2019 bore installation programme, each monitoring bore was equipped with:

- A pressure transducer / logger (Solinst LTC Levelogger Edge) to record water level changes in the bore (set at a 12-hourly reading frequency), as well as EC and temperature at the depth of installation.
- A passive sampler (Hydrasleeve) for the collection of a water sample at the depth of installation. Selected single-completion bores were equipped with two Hydrasleeves if salinity profiles indicated distinct changes in salinity with depth.

The depths of these installations were determined from the salinity profiles. Where a change in salinity was evident with depth, the transducer / logger was installed at or near the transition zone and the passive sampler was installed either above or below the transition zone (or in some cases, both).

Since then, bi-annual groundwater monitoring rounds have been undertaken. Each round comprises groundwater level measurements (logger downloads and manual dip), salinity profiling and groundwater sampling/analysis. In addition, periodic manual water level readings were taken during the 2021 field investigations.

Significant manufacturer problems were experienced with the Solinst loggers with the instruments giving erroneous readings (i.e. unexplained drift or jumps in the data) and / or ceasing to record data. As such, the Solinst loggers were replaced with In-Situ data loggers in December 2021. By that time, sufficient data had been collected to allow a reduced requirement for time-series data and therefore a reduced number of loggers were required. For example, where some bores within a "cluster" (i.e. deep, intermediate and shallow monitoring bores at one location) show similar water levels and EC readings, loggers were no longer required at each of the three bores. Similarly, where EC profiles (recorded during monitoring rounds) provided sufficient information on EC changes, LTC loggers were no longer required and only groundwater level measurements were deemed necessary, rather than time-series EC data as well. In general, time-series EC data is only required in the uppermost aquifer unit in the claypan area, with salinity profiles considered to be sufficient in most other areas (with one or two exceptions). AquaTROLL 200 loggers were installed where groundwater level and EC time-series data is required and LevelTROLL 400 loggers were installed where only groundwater level data is required.

Following the 2021 drilling programme, monitoring bores that had been installed in the Malay Well and Mulga West areas, plus the easternmost monitoring bore in the Mulga East area (MDPZ92015), were added to the baseline monitoring network. Similarly, minor modifications were made to the baseline monitoring network in the Malay Well area following the 2023 bore installation programme.

Details of the current logger and passive sampler installations are summarised in Appendix I.

6. GROUNDWATER DATA ASSESSMENT

6.1 Hydrogeological Units

The results of the 2018/2019, 2021 and 2023 field investigations have been combined with those of previous hydrogeological investigations and publicly available hydrogeological data to develop the conceptual understanding of the area. The investigations and data assessment to date have focused on the Mulga East and Malay Well (tenement) areas, with only a preliminary assessment of the Mulga West area.

Five main hydrogeological units have been identified across the Study Area:

- Tertiary / Quaternary Cover (comprising Basal "Crete", CID/Pisolite, Undifferentiated Tertiary and Upper Calcrete).
- Fresh Jeerinah and Marra Mamba Formations.
- Altered Marra Mamba Formation and West Angela Member.
- Fresh West Angela Member (Wittenoom Formation).
- Dolomite of the Wittenoom Formation.

} Bedrock Units

Each of these units and respective sub-units are described in more detail below. Hydrogeological cross-sections are presented in Figure 6.1 to Figure 6.4, with the locations of the cross-sections shown in Figure 6.5.

6.1.1 Tertiary / Quaternary Cover

Basal Crete: This unit directly overlies the bedrock and occurs in all bores across the valley floor area. It has been intersected at depths of between 46 and 66 mbgl at bores MDPZ7451A, 7452A, 7453A, 7457A, 7458A, 7462A, 7463A, 7468A, 7469A, 7470A, 7471A, MDPZ9211 to MDPZ9216 and MDPZ9222 to MDPZ9225. It ranges in colour from white / cream to beige / yellow-brown and is variable in both composition and nature. It occurs as calcrete, silcrete, dolomite or calcite, and ranges between hard, crystalline, massive, vuggy, brecciated and weathered; potentially weathering to a waxy clay at MDPZ7468 or puggy clay at MDPZ9216. At MDPZ7461, the unit occurs only as 5 m of calcite veining within the black chert bedrock, between 55 and 60 m depth. Similarly, at MDPZ7452A, beneath ~8 m of calcite / calcrete, calcite veining extends into the grey dolomite bedrock. Drilling yields from this unit ranged from 0 to 2 L/s (at MDPZ7468 and MDPZ7469) where it is clayey or highly siliceous, to between 21 and 31 L/s (at MDPZ9211 to MDPZ9216, MDPZ7453 and MDPZ7463) in the centre of the valley area, where the unit is vuggy or brecciated with goethitic staining. This unit is believed to be comparable with the Pinjan Chert, identified in the Fortescue Marsh area to the east (MWH 2015). It may have formed as an alteration and weathering product on the basement; processes that here are assigned to the early Tertiary.

In the Mulga West area, the Basal Crete was intersected at bores MDPZ9218 and MDPZ9219 at depths ranging between 52 and 76 mbgl, with maximum yields ranging between 6 and 16 L/s.

CID / Pisolite (TD2): This unit occurs along the northern flanks of the valley and extends out across the valley floor area. It occurs below the Undifferentiated Tertiary and directly overlies the Basal Crete unit; however, where the Basal Crete unit laterally pinches (on the flanks of the valley), it directly overlies the bedrock. In such locations (where the Basal Crete is absent), it is difficult to differentiate between CID and a hardcap (bedrock) unit and it is believed there may be inconstancies with the logging of these units, including the HPPL mineral exploration logging.

This unit is variable in nature, comprising both magnetic pisoliths (with varying red-brown silt to clay content) and hard, friable or vuggy grey-black CID. On the valley flanks (i.e. at bores MDPZ9207 and MDPZ9209) the unit occurs at shallow depths above the water table. Across the centre of the valley (at bores MDPZ9211 to MDPZ9216 and MPZ9222 to MDPZ9225) the CID / Pisolite unit occurs at depths ranging

between 46 to 56 mbgl, although at MDPZ9215 the unit was not clearly identifiable with pisolites occurring within the Undifferentiated Tertiary and Basal Crete units. Drilling yields from this unit range from <1 L/s (at MDPZ7450, MDPZ7456 and MDPZ7464) up to 16 to 28 L/s (at MDPZ7453, MDPZ9215 and MDPZ9211 to MDPZ9214). Although the unit is mineralised in some areas, drilling yields are also high where no mineralisation has occurred. Bores completed in this unit include MDPZ7449B, 7450B, 7458B, 7460B and MDPB0012.

In the Mulga West area, bores MDPZ9217 to MDPZ9220 intersected the CID / Pisolite unit at depths ranging between 26 and 58 mbgl. Drilling yields ranged between 9 to 22 L/s.

Undifferentiated Tertiary (TD2/TD3): Where present in the valley area, this unit overlays the CID/Pisolite. Further up the flanks of the valley, it may directly overlie bedrock where the CID/Pisolite and Basal Crete "pinches out". The thickness of the unit, where intersected by the hydrogeological drilling, ranges between 12 and 42 m, although it is absent from bores MDPZ9211, MDPZ7457, 7458 and 7461. At these locations the Upper Calcrete directly overlies the CID Pisolite unit. The Undifferentiated Tertiary unit includes both scree/colluvium and detrital material, including alluvial fan material. The unit is predominantly red brown, comprising BIF, chert and quartz gravel with varying silt and clay content / matrix; it may also include magnetic pisoliths (although not as a dominant component). Where intervals of clay occur (i.e. with no or minimal clasts), they tend to be between only 1 to 14 m thick. Drilling yields from this unit are variable, dependent on the clay content and sorting; recorded yields generally ranged between 0 and 12 L/s, although a yield of 16 L/s was recorded at MDPZ9212, and 30 L/s was recorded at MDPZ7452. Production bore MDPB0015 is installed in this unit adjacent to MDPZ7452. The unit represents detritus from the hills to the south interdigitating with the valley fill and is likely to have been deposited over an extended period of time. It has been grouped in this assessment due to the lack of clear hydrogeological divisions within it.

In the Mulga West area, all 2021 bores intersected the Undifferentiated Tertiary unit with drilling yields ranging between 0 and 10 L/s (MDPZ9218).

Upper Calcrete (TD2 Oakover Formation): This unit comprises white to light-brown, unstructured calcrete, often friable and sometimes vuggy; at some locations, such as MDPZ7449, MDPZ7452 and MDPZ7457, it is more siliceous. It occurs across the valley floor area at surface or under a thin cover of alluvium, with a maximum recorded thickness of 46 m at MDPZ9211. Bores completed in this unit (i.e. bores with the slotted interval installed against this unit) include: MDPZ7452C, 7453C, 7457C, 7458C, 7462C, 7470C, 7470C and MDPB0014. Drilling yields from this unit (excluding MDPB0011) ranged from 2 to 20 L/s at MDPZ7471 and MDPZ7458 respectively, with a yield of 0.1 L/s recorded at MDPZ7449 where half of the unit occurs above the water table, resulting in a saturated thickness of only 4 m.

In the Mulga West area, the Upper Calcrete was intersected by the 2021 bores nearest the Fortescue River (MDPZ9218 to MDPZ9221), at depths ranging between 0 and 44 mbgl. Drilling yields ranged between 0 (due to the limited saturated thickness of the aquifer unit) to 12 L/s.

Alluvium: A thin layer of silty alluvium (up to ~4 m thick) covers much of the lower lying ground of Study Area. Near the claypans (i.e. MDPZ7468 and MDPZ7471), it comprises 2 to 3 m of clay. It predominantly occurs above the water level and is therefore not considered as a hydrogeological unit.

Summary: The Tertiary overburden forms a highly transmissive and continuous aquifer within the valley of the Study Area. Maximum thicknesses of up to approximately 60 m occur in the middle of the valley, thinning on the valley slopes.

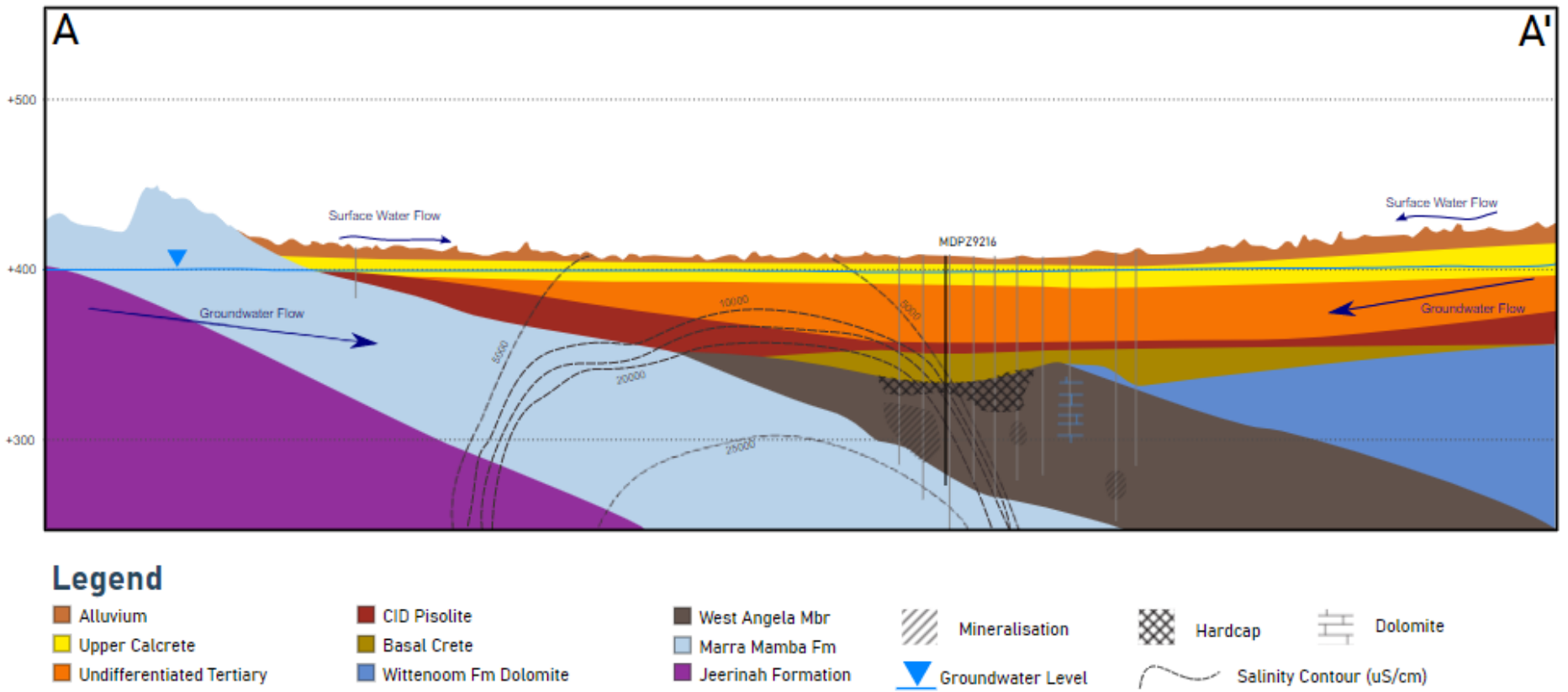


Figure 6.1 Hydrogeological Section A (looking east)

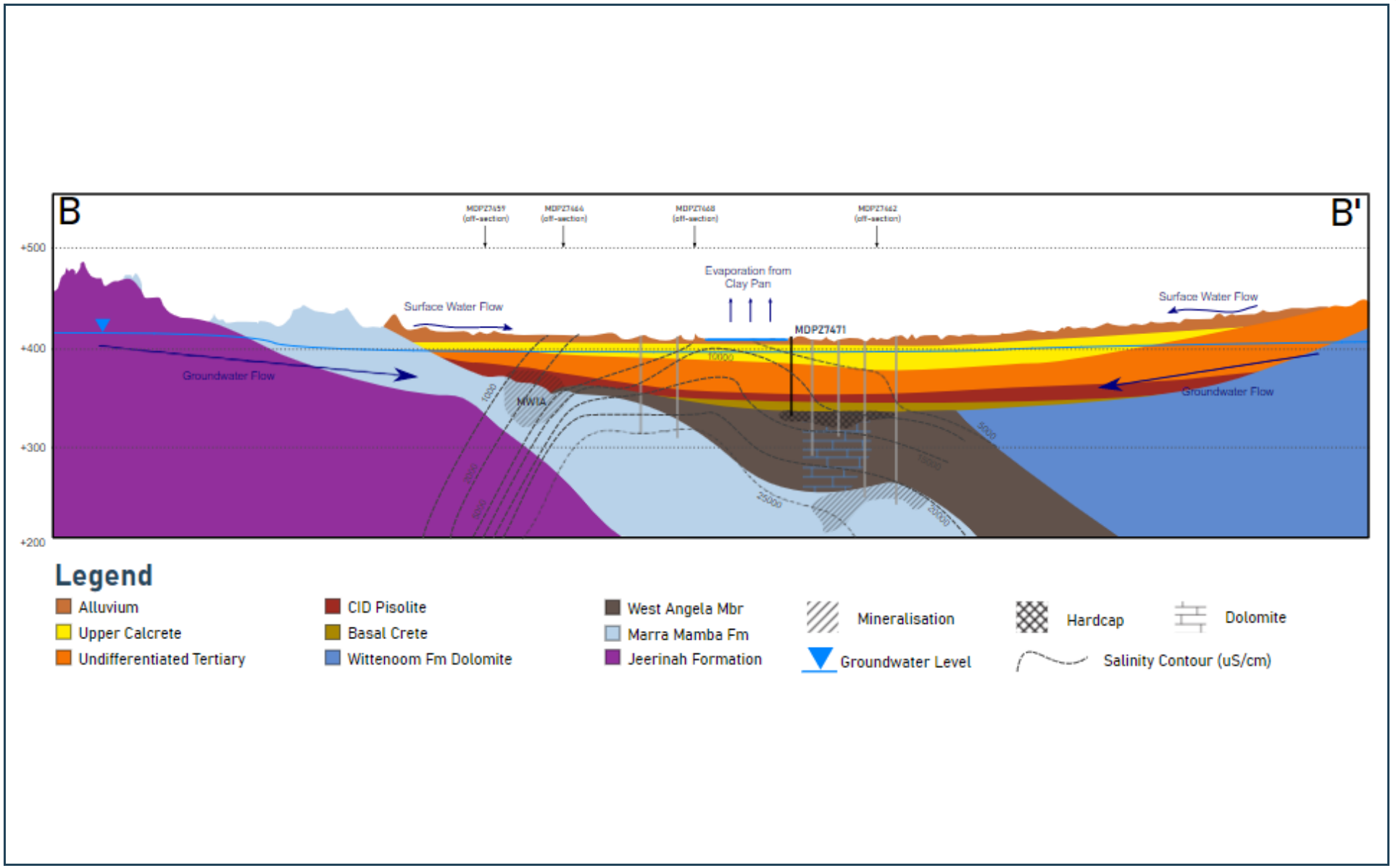


Figure 6.2 Hydrogeological Section B (looking east)

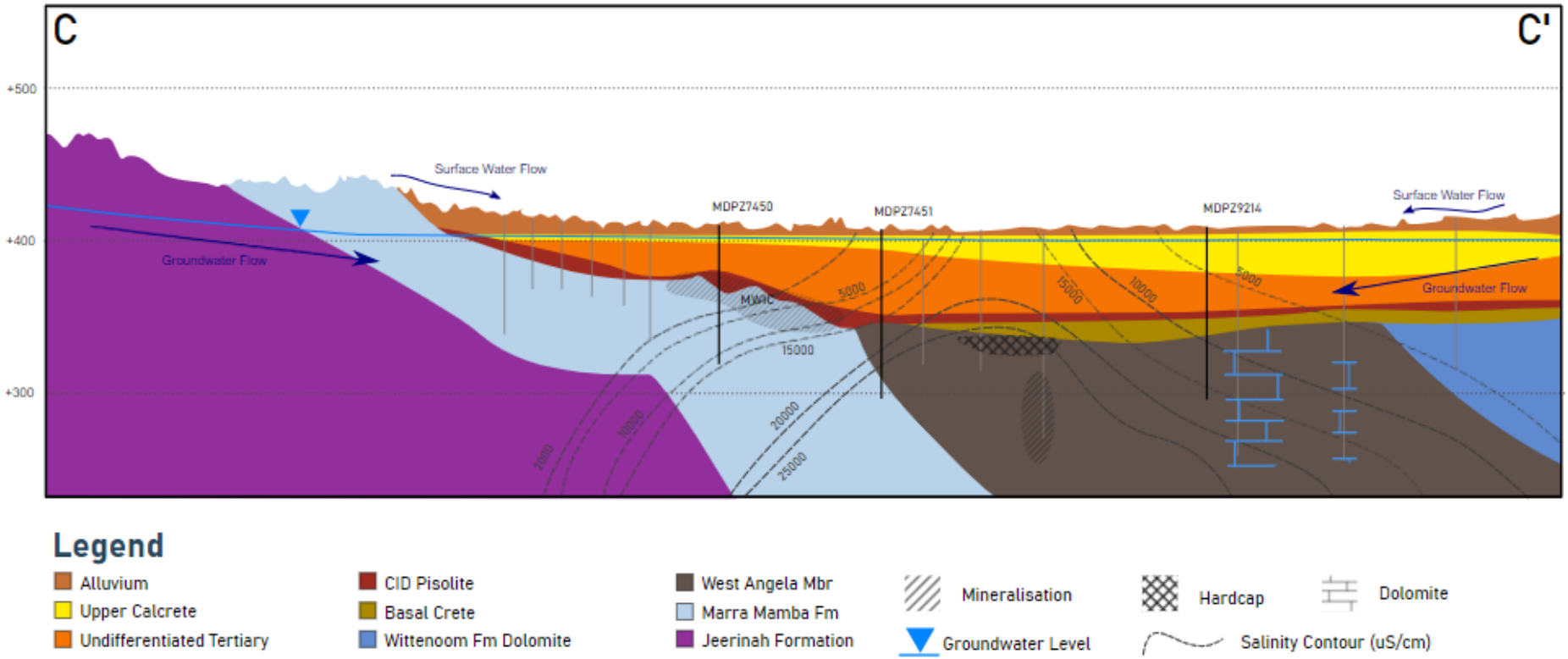


Figure 6.3 Hydrogeological Section C (looking east)

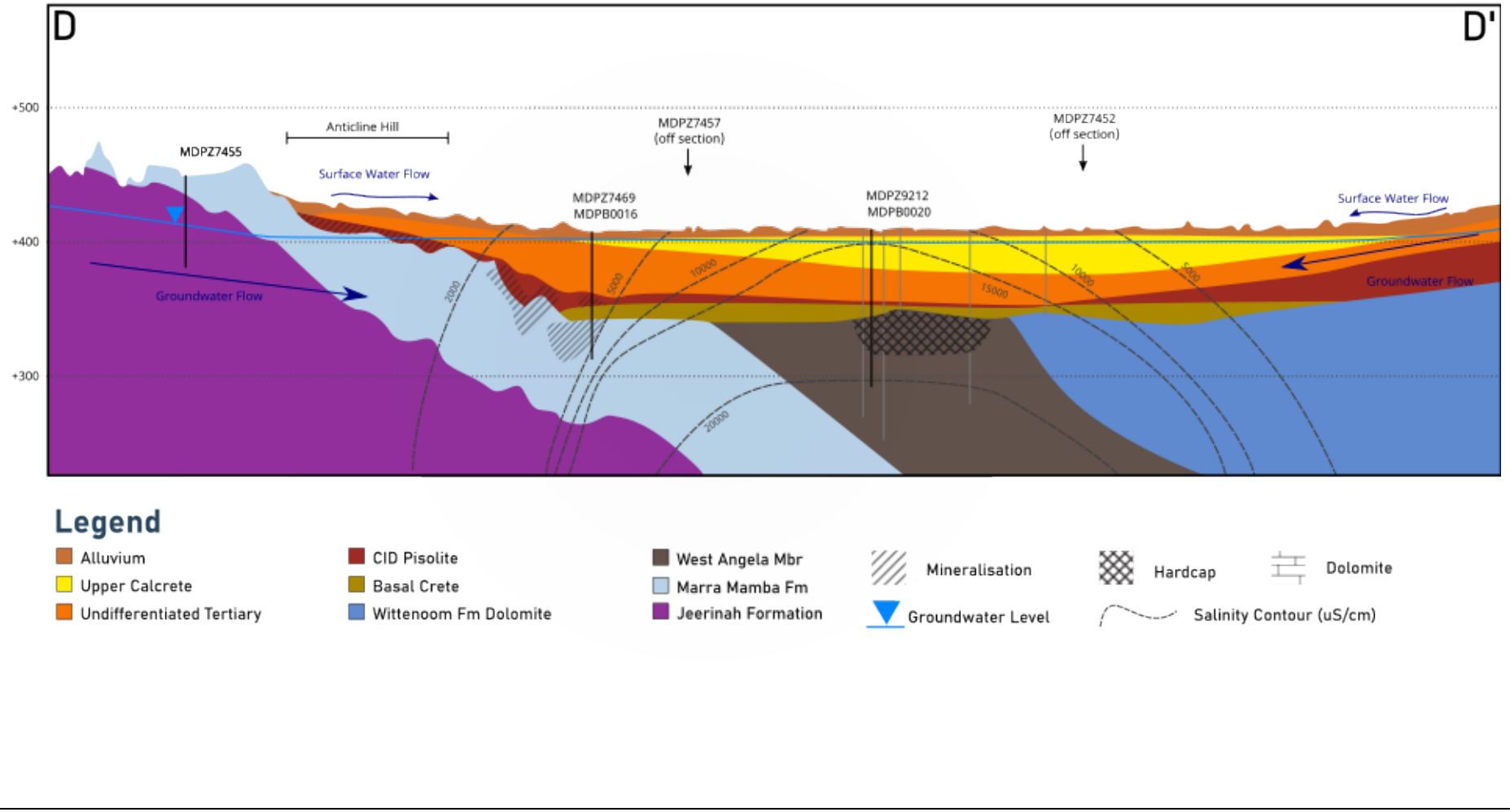


Figure 6.4 Hydrogeological Section D (looking east)

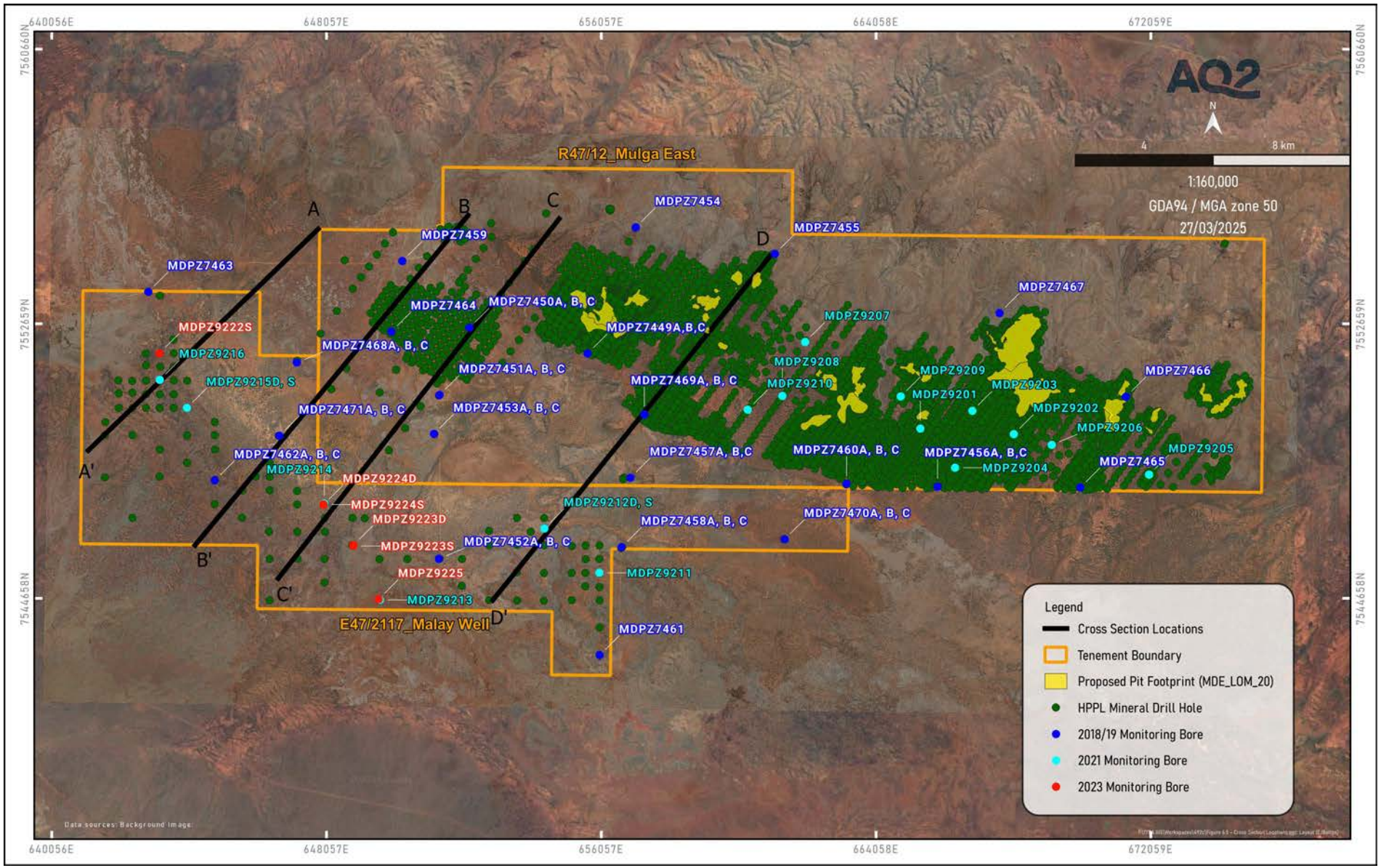


Figure 6.5 Location of Hydrogeological Sections

6.1.2 Bedrock Units

Fresh Jeerinah Formation & Marra Mamba Formation: The Jeerinah Formation is the oldest stratigraphic unit in the Study Area and outcrops along the northern Study Area boundary. Where fresh, this unit comprises black, pyritic and carbonaceous shale with minor chert beds and weathers to pink, brown and/or white puggy clay.

Overlying the Jeerinah Formation is the Nammuldi Member of the Marra Mamba Formation, with similar carbonaceous black shale occurring at its base. In the HPPL geological model, this unit is classified as "dolomitic Nammuldi" (code: DNAM), however, it is often logged on site as Jeerinah Formation given the similarities of the two units. The dolomitic Nammuldi Member and Jeerinah Formation have been grouped as a single hydrostratigraphic unit, referred to as "the Jeerinah".

The northernmost monitoring bores, MDPZ7454 and MDPZ7455, are screened against the Jeerinah, with the overlying chert of the Marra Mamba Formation being above the water table. Airlift yields during the drilling of these bores were generally very low (<0.1 L/s) although yields at total depth (i.e. 60 mbgl) increased to 0.3 and 1.3 L/s respectively, indicative of very minor intervals of increased permeability at MDPZ7455.

Overlying the Jeerinah hydrostratigraphic unit, the Marra Mamba Formation comprises interbedded BIF, shale and chert. The Marra Mamba Formation above the dolomitic Nammuldi Member has been sub-divided into two main hydrostratigraphic units based on its hydrogeological characteristics; low permeability is categorised as "Fresh Marra Mamba" and increased (secondary) permeability is categorised as "Altered Marra Mamba".

Bores MDPZ7466 and MDPZ7467 are screened against lower permeability (Fresh Marra Mamba) and the Jeerinah at depth. Although the airlift yields from these bores were 5 and 3.5 L/s respectively, yields occurred from discrete intervals (i.e. at ~46 m in MDPZ7466 and at the contact of the Jeerinah at ~56 m in MDPZ7467) and are indicative of minor fracture zones with increased permeability.

Altered Marra Mamba: Of the 14 drill locations completed in 2018/19 and the ten 2021 drill locations that intersected the Marra Mamba, all demonstrated secondary permeability to some extent. Drilling yields in most bores ranged between 14 and ~35 L/s, with only MDPZ7466 and MDPZ7467 (to the northeast of the orebodies) having lower yields of 5 and 3.5 L/s respectively (as mentioned above). The increased permeability in the other 22 holes occurs along the northern flanks of the valley (both within and between the identified orebodies), along the southern margin of the orebody area and extends south beneath the valley. Secondary permeability appears to be related to mineralisation, weathering and / or fracturing, hence termed "altered".

The Altered Marra Mamba unit can be further categorised into Marra Mamba Ore and Unmineralised / Fractured Marra Mamba. Monitoring bores MDPZ7465, 7469B, 9201, 9202, 9203 and 9204 were all drilled within the proposed pit areas with maximum yields in the Marra Mamba Ore ranging between 14 and 25 L/s. Production bores MDPB001, MDPB002, MDPB0016 and MDPB0017 all intersect mineralised CID and Marra Mamba Ore. Many of the 2021 drill sites (MDPZ9205 to MDPZ9210) targeted Unmineralised Marra Mamba between the orebodies with maximum drilling yields through the Marra Mamba unit generally ranging between 10 and 16 L/s, although MDPZ9209 had a lower yield of 8 L/s. Increased yields were recorded at the contact between the Marra Mamba Formation and the Jeerinah hydrostratigraphic unit at bores MDPZ9207 (where the yield increased from 10 to 14 L/s) and MDPZ9210 (where the yield increased from 16 to 35 L/s). Production bores MDPB004, 5, 6, 13 and 19 are installed in the Altered Marra Mamba unit, noting that all except MDPB0013 also intersect the Jeerinah at depth, with MDPB005, 6 and 19 also indicating increased yields at the Marra Mamba – Jeerinah contact.

Although weathering of the Marra Mamba generally results in enhanced permeability, at bores MDPZ7464 and MDPZ7451A weathering of a shale unit has resulted in a low permeability saprolitic clay horizon overlying the permeable aquifer unit. At MDPZ7464 the saprolite is 12 m thick (between 52 and 64 m depth), whilst at MDPZ7451A it is 26 m thick (between 66 to 92 m).

There are only limited hydrogeological drilling data for the Mulga West area, however, enhanced permeability in the Marra Mamba Formation appears to generally be limited to weathered / mineralised / hardcap zones immediately below the Tertiary overburden, with drill samples between 86 and 90 m depth at MDPZ9219 also indicative of a permeable fracture zone. Although airlift yields during drilling increased at the base of most holes, this was associated with open-hole drilling (therefore indicative of cumulative yields) and was generally associated with very hard drilling and slow penetration rates, with no evidence in the drill cuttings of enhanced permeability.

West Angela Member: Similar to the Marra Mamba Formation, the West Angela Member comprises interbedded BIF, shale and chert with some beds of dolomite. It directly overlies the Mt Newman Member of the Marra Mamba Formation and sub-crops the Tertiary deposits, beneath the valley floor. The West Angela Member has also been sub-categorised based on its hydrogeological characteristics, with "West Angela Hardcap" and "West Angela Ore" units having increased (secondary) permeability to the "Weathered West Angela Member".

Within the Malay Well area, increased permeability was encountered within a mineralised zone directly underlying the Basal Crete at bores MDPZ9211, 9212D and 9215D, with maximum drilling yields within this unit ranging between 24 and 33 L/s. At depths ranging between 60 and 76 mbgl the unit is dark grey / black with a metallic lustre, moderately vuggy and with goethitic staining. Whilst at MDPZ9212D, the unit extends to 90 mbgl, becomes vuggier and comprises yellow-brown limonitic shale with a honeycomb structure. Production bore MDPB0020 is installed at this location and yields of ~140 L/s were estimated when drilling through this unit.

As outlined above, the differentiation between CID and hardcap is difficult and consideration was given as to whether these mineralised zones are part of a locally incised channel(s), beneath the Basal Crete, infilled with CID (as is known to occur to the west from Weelumurra downstream towards Millstream).

Based on the assays of the Malay Well HPPL drilling, similar zones of mineralisation and composition were mapped and compared to publicly available magnetic data for the area (DMIRS 2016) (Figure 6.6). Attempts were made to map a potential channel thalweg through the Malay Well area. Although a channel-like feature is evident in the Mulga West area near the mapped mineralisation of similar composition, no incised channel could be identified in the Malay Well area. Instead, it is considered that where BIF units of the West Angela Member (and Marra Mamba Formation) have previously been exposed to extensive weathering (i.e. immediately underlying the Tertiary overburden) a permeable hardcap has formed. Where this unit is deeper (i.e. at MDPZ9212D / MDPB0020), it may be due to deeper weathering / alteration along an exposed fault / structure or at the contact between the West Angela and Paraburdoo Members. At this location in particular, weathering has resulted in a highly permeable, honeycomb-like texture. In contrast, where shale of the West Angela Member (and Marra Mamba Formation) has been exposed to weathering, it may occur as pale-coloured, waxy or puggy clay (i.e. at MDPZ9215D underlying the hardcap and at MDPZ9214, 9216 and 9222). Although this puggy clay could be locally confining, current data do not show that it occurs as an extensive and continuous layer.

Based on the HPPL geological model, the recent hydrogeological drilling at Mulga West did not intercept the West Angela Member; however, the HPPL site logging interpreted 6 m of West Angela Member at MDPZ9218 (directly underlying the Tertiary overburden and overlying the Marra Mamba Member).

Airlift yields were recorded by HPPL at the completion of mineral exploration holes drilled by RC methods in the Mulga West area. This data indicates higher yields in the vicinity of shallow mineralisation, possibly associated with hardcap, within the West Angela Member to the west / west-northwest of MDPZ9219; however, these higher yields could also be associated with increased permeability in the Tertiary unit or potentially bedrock fracturing (similar to MDPZ9212).

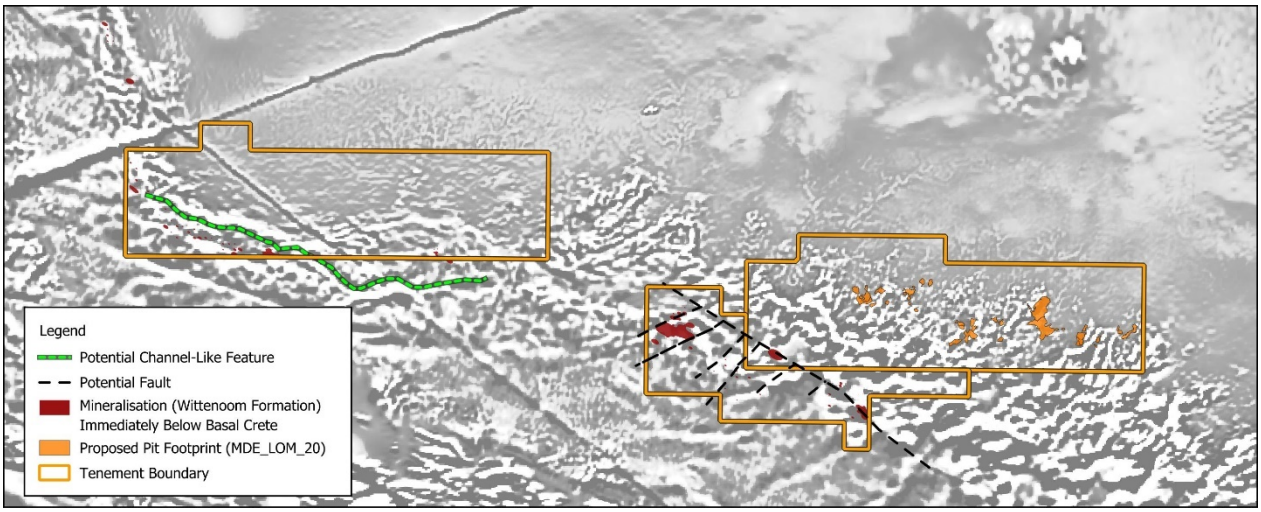


Figure 6.6 Examples of Inferred Geological Features for Mulga West & Malay Well Tenements from Magnetic Data

West Angela Ore is intersected at bores MDPZ9215D, MDPZ9216 and MDPZ9222 in the Malay Well area, below the West Angela Hardcap at depths of up to ~130 mbgl. Drilling yields through this unit ranged between 12 and 35 L/s at MDPZ9215D, between 5.5 and 27 L/s at MDPZ9216 and between 12 and 16 L/s at MDPZ9222, increasing to 43 L/s below the main mineralised interval.

Weathered West Angela is intersected at MDPZ9214. Although calcite veining is present immediately below the Basal Crete, with drilling yields of ~22 L/s, below this is predominantly yellow-brown to grey and beige shale with minor bands of chert and dolomite. Drilling yields through this unit ranges between 3 and 6 L/s and this is anticipated to be representative of the majority of the West Angela Member in the Malay Well area.

Highly weathered bedrock comprising shale, dolomite and BIF was intersected at MDPZ9212D and MDPB0020; however, as indicated above, this is anticipated to be a localised zone potentially associated with a fault / structure or at the contact between the West Angela and Paraburdoo Members, rather than being representative of the Weathered West Angela unit. Drilling yields at MDPZ9212D reached ~60 L/s and high yields prevented further drilling of both this bore and the adjacent production bore (MDPB0020).

Dolomite of the Wittenoom Formation (presumed to be Paraburdoo Member) overlies the West Angela Member and sub-crops the Tertiary deposits beneath the valley floor. It is intersected by bores MDPZ9211, 9213, 7452A, 7458A, 7461 and 7462A. Where intersected, the dolomite is generally light grey, fresh, crystalline and hard, with no recordable increase in airlift yields during drilling. However, at MDPZ9211 (between 76 and 82 mbgl) and MDPZ7458A (between 66 and 68 mbgl), a weathered zone of dolomite (vuggy at MDPZ7258A) yielded 24 and ~30 L/s respectively, indicating significant secondary permeability. A 5 L/s increase in yield at MDPZ7452A may also be associated with increased permeability at the top of the dolomite. Thus, from the drilling to date, the dolomite of the Wittenoom Formation is likely to have discontinuous zones of significant permeability.

Complexities within the Wittenoom Formation: In the Malay Well area, between the sub-cropping West Angela Member and Paraburdoo Member described above, there appears to be a zone of very variable bedrock lithology where neighbouring HPPL drill holes show thick intervals of fresh grey dolomite adjacent to interbedded shale, BIF, chert and dolomite of what appears to be West Angela Member (i.e. BIF, chert, shale) overlying what appears to be Paraburdoo Member (i.e. thick, fresh, crystalline dolomite). It is anticipated that this is due either to:

- Faulting resulting in the juxta-positioning of the Paraburdoo and West Angela Members; or
- The West Angela and Paraburdoo Members (and potentially other members of the Wittenoom Formation) in fact not being present in the area, but instead being represented by the stratigraphically equivalent Carawine Dolomite (Kepert 2018).

Although magnetic data indicates that faulting may be present in this area of Malay Well (refer Figure 6.6), the presence and orientation (as well as the hydraulic characteristics) of any potential faulting is unknown and is recognised as an uncertainty.

Summary: The Study Area is underlain by low permeability Jeerinah Formation and unmineralised Marra Mamba Formation that form a basement aquitard with minor local fractured aquifers. A highly transmissive and continuous aquifer is hosted in the mineralised, fractured and weathered Marra Mamba Formation. The overlying West Angela Member of the Wittenoom Formation forms a moderately permeable aquifer unit with localised (discontinuous) zones of enhanced permeability associated with mineralisation and extreme weathering / alteration. To the south of claypan area, this aquifer is overlain by the Paraburdoo Member of the Wittenoom Formation that forms a discontinuous fractured rock aquifer in generally low-permeability basement. Additional faulting may also result in the juxtaposition of the West Angela Member aquifer and Paraburdoo Member aquitard units, potentially resulting in reduced hydraulic connection along strike.

6.2 Aquifer Parameters

Estimates of aquifer transmissivity have been derived from the hydraulic testing data. AQTESOLV software (by HydroSOLVE Inc.) was used for the analysis of the production bore pumping tests, whilst manual straight-line curve-fitting analyses were applied to the airlift micro- and mini- pumping test and airlift recovery test data. Analyses plots are presented in Appendix F.

For all analyses, the estimated transmissivity (T) has been divided by the assumed aquifer thickness (b) to provide an estimate of permeability (k). The estimated aquifer parameters derived from the pumping tests on the recent and historic production bores are presented in Table 6.1whilst the estimated aquifer permeabilities derived from all the hydraulic testing are presented in Table 6.2.

Table 6.1 Hydraulic Parameters from Production Bore Test Pumping

Pumped Bore (Aquifer Unit)	Test	Monitoring Data	Analytical Method	T (m^2/d)	k (m/d)	S	Summary
MDPB001 (Detritals & Altered Marra Mamba)#	Constant Rate	MD0574	Dual Porosity	729	15	0.02	Summary of Analysis Average T = 1149 m^2/d Average S = 0.138 Average k = 24 m/d b = 48 m
			Logan's Approximation	81	2	0.15	
			Neuman	904	19	-	
			Theis (Cooper-Jacob Correction)	884	18	0.66	
		MD0573	Dual Porosity	2930	61	0.00005	
			Logan's Approximation	84	2	0.0004	
			Neuman	953	20	-	
			Theis (Cooper-Jacob Correction)	2630	55	0.00027	
MDPB002 (Detritals & Altered Marra Mamba)#	Constant Rate	MDPB002	Theis (Cooper-Jacob Correction)	500	31	-	Summary of Analysis Average T = 405 m^2/d Average S = 0.0025 Average k = 25 m/d b = 16 m
		MD0551	Dual Porosity	486	30	0.001	
			Logan's Approximation	347	22	0.004	
			Neuman	488	31	-	
			Theis (Cooper-Jacob Correction)	276	17	0.0026	
	Recovery	MDPB002	Theis (Cooper-Jacob Correction)	337	21	-	
		MD0551	Theis (Cooper-Jacob Correction)	404	25		
MDPB004 (Altered Marra Mamba)#	Constant Rate	MDPB004	Estimation from specific capacity	3430	132	-	Summary of Analysis Average T = 4526 m^2/d Average S = n/a Average k = 174.1 m/d b = 26 m
			Jacob Straight Line (early time)	6081	234	-	
			Jacob Straight Line (late time)	3437	132	-	
	Recovery	MDPB004	Residual Drawdown	5856	225	-	
MDPB005 (Altered Marra Mamba)#	Constant Rate	MDPB005	Estimation from specific capacity	377	15.7	-	Summary of Analysis Average T = 205 m^2/d Average S = 8.3x10-5 Average k = 8.5 m/d b = 24 m
			Jacob Straight Line (early time)	82	3.4	-	
			Jacob Straight Line (late time)	334	13.9	-	
		MD0790	Jacob Straight Line (early time)	4506*	187.7*	8.3x10-5	
			Jacob Straight Line (late time)	4506*	187.7*	8.3x10-5	
	Recovery	MDPB005	Residual Drawdown	111	4.6	-	
		MD0790	Residual Drawdown (late data)	-	-	5.5x10-4	

Pumped Bore (Aquifer Unit)	Test	Monitoring Data	Analytical Method	T (m^2/d)	k (m/d)	S	Summary
MDPB006 (Altered Marra Mamba)#	Constant Rate	MDPB006	Estimation from specific capacity	1597	48.4	-	Summary of Analysis Average T = 1817 m^2/d Average S = 2.8x10-3 Average k = 55.1 m/d b = 33 m
			Jacob Straight Line (early time)	3117	94.4	-	
			Jacob Straight Line (late time)	836	25.3	-	
		MD1297	Jacob Straight Line (early time)	3117	94.4	3.9x10-3	
			Jacob Straight Line (late time)	945	28.6	1.2x10-3	
	Recovery	MDPB006	Residual Drawdown	1914	58	-	
		MD1297	Residual Drawdown (late data)	2797	84.8	-	
MDPB0011 (Upper Calcrete & Undiff Tert / Alluvial Fan)	Constant Rate	MDPB0011	Cooper-Jacob early time	528	44	-	Summary of Analysis Average T = 399 m^2/d Average Sy = 0.2% Average k = 33 m/d b = 12 m
			Cooper-Jacob late time	174	15	-	
			Theis	327	27	-	
		MDPB7450C	Theis	298	25	0.2%	
	Recovery	MDPB0011	Theis	642	54	-	
		MDPB7450C	Theis	701	58	-	
MDPB0012 (Pisolite / Hardcap)	Constant Rate	MDPB0012	Cooper-Jacob	843	22	-	Summary of Analysis Average T = 805 m^2/d Average S = n/a Average k = 21 m/d b = 38 m
			Theis	785	21	-	
		MDPZ7449B	Theis	5078*	134*	-	
	Recovery	MDPB0012	Theis	788	21	-	
MDPB0013 (Marra Mamba)	Constant Rate	MDPB0013	Cooper-Jacob	556	12	-	Summary of Analysis Average T = 441 m^2/d Average S = n/a Average k = 10 m/d b = 46 m
			Theis	689	15	-	
		MDPZ7460A	Theis	6361*	138*	-	
	Recovery	MDPB0013	Theis	346	8	-	
		MDPZ7460A	Theis	285	6	-	
MDPB0014 (Upper Calcrete)	Constant Rate	MDPB0014	Cooper-Jacob	1881	63	-	Summary of Analysis Average T = 1900 m^2/d Average Sy = n/a Average k = 63 m/d b = 30 m
			Theis	1591	53	-	
			Theis	1941	65	-	
		MDPZ7457C	Theis	1950	65	1.20E-07*	
	Recovery	MDPZ7457C	Theis	2185	73	-	

Pumped Bore (Aquifer Unit)	Test	Monitoring Data	Analytical Method	T (m^2/d)	k (m/d)	S	Summary
MDPB0015 (Undiff Tertiary)	Constant Rate	MDPB0015	Theis	12380	688	-	Summary of Analysis Average T = 6573 m^2/d Average S = n/a Average k = 365 m/d b = 18 m
		MDPZ7452B	Theis	15250	847	-	
	Recovery	MDPB0015	Theis	1504	84	-	
MDPB0016 (Undiff Tert / CID / Basal Crete / Mineralised MM)	Constant Rate	MDPB0016	Cooper-Jacob early time	647	8	-	Summary of Analysis Average T = 819 m^2/d Average S = $4x10^{-5}$ Average k = 10 m/d b = 78 m
			Hantush-Jacob (Leaky)	619	8	-	
		MDPZ7469B (MM only)	Hantush-Jacob (Leaky)	619	8	0.00005	
			Cooper-Jacob early time	731	9	2.37E-05	
			Cooper-Jacob early time (manual)	1265	16	-	
		MDPZ7469C (Undiff Tert / CID)	Cooper-Jacob early time (manual)	1265	16	0.007	
	Recovery	MDPB0016	Theis (recovery)	585	8	-	
MDPB0017 (CID / Mineralised MM)	Constant Rate	MDPB0017	Cooper-Jacob early time	4433	57	-	Summary of Analysis Average T = 4669 m^2/d Average S = $8x10^{-4}$ Average k = 57 m/d b = 78 m
			Cooper-Jacob early time (manual)	2875	37		
			Theis	3524	45	-	
		MDPZ9204	Cooper-Jacob early	6426	82	5.38E-04	
			Theis	6086	78	0.0011	
		MDPZ7456B	Theis	10150*	145*	0.001533*	
MDPB0018 (CID / Unmin MM)	Constant Rate	MDPB0018	Cooper-Jacob early time	751	10	-	Summary of Analysis Average T = 1065 m^2/d Average S = $4x10^{-3}$ Average k = 13 m/d b = 78 m
			Theis	996	14		
		MDPZ9733	Cooper-Jacob early time	732	10	0.0004	
			Theis	535	7	0.0006	
		MDPZ9206 (sealed at depth, MM only)	Theis	1741	24	0.0085	
			Cooper-Jacob early time	1785	24	0.006	
	Recovery	MDPB0018	Theis (recovery)	915	13	-	
		MDPZ9206 (sealed at depth, MM only)	Theis (recovery)	2420*	33*	-	

Pumped Bore (Aquifer Unit)	Test	Monitoring Data	Analytical Method	T (m^2/d)	k (m/d)	S	Summary
MDPB0019 (CID / Unmin MM)	Constant Rate	MDPB0019	Cooper-Jacob early time	720	19	-	Summary of Analysis Average T = 722 m^2/d Average S = $1.4x10^{-3}$ Average k = 19 m/d b = 38 m
			Theis	708	19	-	
			Hantush-Jacob (Leaky)	698	18	-	
		MDPZ9207	Cooper-Jacob early time	693	18	0.0013	
			Theis	680	18	0.0013	
			Hantush-Jacob (Leaky)	698	18	0.0015	
	Recovery	MDPB0019	Theis (recovery)	859	23	-	
MDPB0020 (Hardcap / Dolomite)	Constant Rate	MDPB0020 (Sealed below Basal Crete)	Cooper-Jacob early time	5238	125	-	Summary of Analysis Average T = 5516 m^2/d Average S = 0.04 Average k = 131 m/d b = 42 m
			Theis	6388	152	-	
		MDPZ9212D	Cooper-Jacob early time	5455	130	0.1467	
			Hantush-Jacob (Leaky)	5783	138	0.0113	
		MDPZ9212S	Hantush-Jacob (Leaky)	9510*	226*	0.001335*	
		MDPZ5355	Cooper-Jacob early time	5663	135	0.0008	
			Hantush-Jacob (Leaky)	4740	113	0.0003	
	Recovery	MDPB0020 (Sealed below Basal Crete)	Theis (recovery)	5342	127	-	

T = transmissivity, S = Storativity (for confined aquifers), Sy = Specific Yield (for unconfined aquifers), k = permeability, b = saturated aquifer thickness
MM = Marra Mamba Formation
Representative storage values (S and Sy) could not always be derived from the test data.
Average = geometric mean
# Analyses results for bores MDPB001 to MDPB006 taken from MWH reports (MWH 2009 & 2014).
* Data considered to be outliers and not included in statistics.

Table 6.2 Hydraulic Parameters from all Hydraulic Testing

Hole ID	Cased Depth (m)	Screened Geology	Max Drilled Airlift Yield (L/s)	Completed Airlift Yield (L/s)	Testing Method	Effective T (m^2/d)		Aquifer Thickness (m)	k (m/d)		Average k (m/d)
						Pumping	Recovery		Pumping	Recovery	
MDPZ7452C	32	Upper Calcrete	7	2	Micro CRT	237		27	8.79		10
MDPZ7453C	17	Upper Calcrete	5	0.8	Micro CRT	474	316	11	43.13	28.75	
MDPZ7457C	35	Upper Calcrete	14	2.8	Micro CRT	237	237	25	9.49	9.49	
MDPZ7458C	41	Upper Calcrete	20	0.5	Airlift Recov		26	12		2.20	
MDPZ7462C	35	Upper Calcrete	12.2	1.23	Micro CRT	700	9804**	27	25.94		
MDPZ7470C	23	Upper Calcrete	6	2.2	Micro CRT	79		16	4.94		
MDPZ7471C	21	Upper Calcrete	4.4	1.2	Micro CRT	107	96	14	7.66	6.89	
MDPB0014	35	Upper Calcrete	12	8	CRT	1900		30	63		
MDPZ7449C	10.65	Upper Silcrete (+ Pisolititic Clay)	0.1	0.01	Micro CRT	22	23	6	4.00	4.21	
MDPZ7459	28	Alluvial Fan Gravel (Undiff Tert)	3.5	0.4	Micro CRT	95	79	17	5.63	4.69	8
MDPZ7450C	22	Undiff Tertiary	5	0.7	Micro CRT	119	237	14	8.47	16.94	
MDPZ7451C	44	Undiff Tertiary	5	1.4	Micro CRT	264	158	32	8.24	4.94	
MDPZ7460C	29.3	Undiff Tertiary	3.7	1.4	Micro CRT	316	506	17	18.28	29.25	
MDPZ7469C	52.5	Undiff Tertiary	4.3	2.2	Micro CRT	207	134	46	4.53	2.94	
MDPZ7470B	49.1	Undiff Tertiary	10	1.8	Micro CRT	117	201	25	4.64	8.02	
MDPZ7462B	58.5	Undiff Tertiary	12	1.8	Micro CRT	41		23	1.82		
MDPZ7468C	52	Undiff Tertiary	11.2	2.1	Micro CRT	101	101	34	2.98	2.98	
MDPB0011	23.5	Undiff Tertiary / Upper Calcrete	2.9	3.8	CRT	399		12	33		
MDPB0015	52	Undiff Tertiary	50	30	CRT	6573		18	365		
MDPZ7470B	49.1	Undiff Tertiary	10	1.8	Airlift Recov		114	25		4.54	

Hole ID	Cased Depth (m)	Screened Geology	Max Drilled Airlift Yield (L/s)	Completed Airlift Yield (L/s)	Testing Method	Effective T (m^2/d)		Aquifer Thickness (m)	k (m/d)		Average k (m/d)
						Pumping	Recovery		Pumping	Recovery	
MDPZ7450B	42	CID/Pisolite	5	1.6	Micro CRT	474.41	237.20	22	21.56	10.78	14
MDPZ7453B	48	CID/Pisolite & Undiff Tertiary	22	2.4	Micro CRT	158.14	237.20	23.5	6.73	10.09	
MDPZ7456C	41	CID/Pisolite & Undiff Tertiary	10	1.1	Micro CRT	196.79	553.48	37	5.32	14.96	
MDPZ7458B	52	CID/Pisolite	20	2.75	Airlift Recov		830.22	9		92.25	
MDPB0012	46.5	Pisolite / CID / Hardcap	15	15	CRT	805		38	21		
MDPZ7457B	59	CID/Pisolite & Basal Calcrete	20	3.5	Micro CRT	237.20	296.51	24	9.88	12.35	
MDPZ7453A	72.5	Basal Calcrete	25	3	Micro CRT	276.74	184.49	23	12.03	8.02	9
MDPZ7453A	72.5	Basal Calcrete	25	3	Airlift Recov		94.88	23		4.13	
MDPZ7451B	62	Basal Calcrete	10	1.5	Micro CRT	39.53	47.44	12	3.29	3.95	
MDPZ7468B	65	Basal Calcrete / Silcrete	15.2	2.8	Micro CRT	126.51	168.68	11	11.50	15.33	
MDPZ7452A	72	Basal Calcite & Dolomite	45	3.5	Airlift Recov		737.97	22.5		32.80	
MDPZ9206	89	Unmin MM / Jeerinah	16	5.5	Mini CRT	822		30	27.40		10
MDPZ9208	74	Unmin MM / Jeerinah	16	5.5	Mini CRT	633		36	17.58		
MDPZ9209	70	Unmin MM (no inc yield in Jeerinah)	8	4.5	Mini CRT	216		32	6.76		
MDPZ9210	80	Unmin MM (Jeerinah)	35	10	Mini CRT	513		36	14.25		
MDPZ7450A	102	Unmin MM (below CID)	35	1.95	Micro CRT	95	237	44	2.16	5.39	
MDPZ7456A	120	Unmin MM (deep)	20	2.75	Micro CRT	44	43	20	2.21	2.13	
MDPB004	54.5	Unmin MM/ Jeerinah	6	unknown	CRT	4526		26	174		
MDPB005	62	Unmin MM (below CID)/Jeerinah	14	unknown	CRT	205		24	8.5		
MDPB0013	112	Unmin MM (down dip of pit)	21	10	CRT	441		52	8.5		
MDPB0019	77	Unmin MM / Jeerinah	24	10	CRT	722		32	23		

Hole ID	Cased Depth (m)	Screened Geology	Max Drilled Airlift Yield (L/s)	Completed Airlift Yield (L/s)	Testing Method	Effective T (m^2/d)		Aquifer Thickness (m)	k (m/d)		Average k (m/d)
						Pumping	Recovery		Pumping	Recovery	
MDPB0018	91	Undiff Detritals /CID/Unmin Marra Mamba	42	38	CRT	1065		78	13		24
MDPB006	60	CID (2m) / Unmin MM	15	unknown	CRT	1817		33	55		
MDPZ7469A	101	MM (below main ore zone)	>25	2.1	Micro CRT		115	11		10.46	13
MDPZ7469A	101	MM (below main ore zone)	>25	2.1	Airlift Recov		369	11		33.54	
MDPZ7456B	62	Mineralised MM (upper)	20	3	Micro CRT	138	89	18	7.69	4.92	
MDPB002	32	Mineralised MM (poss. Detritals)	unknown	unknown	CRT	405		16	25		
MDPB001	55	CID / Mineralised MM			CRT	1149		48	24		24
MDPB0016	88	CID / Mineralised MM / Jeerinah	27.5	40	CRT	819		78	10		
MDPB0017	100	Undif Tert/CID/Mineralised MM	60	45	CRT	4669		78	57		
MDPB0020	112.5	West Angela / Fault? (Hardcap/Shale/Dolomite/Chert)	~140	50	CRT	5516		42	131		131
MDPZ9215D	130	Hardcap / West Angela (Min & Unmin)	47	12	Airlift Recov	1898	3795	66	28.75	57.50	20
MDPZ9216	119.5	Hardcap / West Angela (Min)	34	8	Airlift Recov	633	1265	45	14.21	28.43	
MDPZ7470A	104	Hardcap / West Angela	>30	4	Airlift Recov		553	40		13.94	
MDPZ7471A	78	Hardcap / West Angela	43	3.3	Micro CRT	148		14	10.54		
MDPZ7454	58	Jeerinah	0.3	0.3	Falling Head	0.68		44	0.015		0.02
MDPZ7455	60	Jeerinah	1.25	0.25	Falling Head	0.83		48	0.017		
MDPZ7466	64.8	Fresh Marra Mamba / Jeerinah	4.8	0.02	Falling Head	0.42		27	0.015		0.02
MDPZ7467	64	Fresh Marra Mamba / Jeerinah	3.5	0	Falling Head	0.58		27	0.022		

* Parameters are only derived from Recovery data for Airlift Recovery and Falling Head Tests. Drawdown data has significant "noise" resulting from the airlifting process, therefore the recovery provides better data for analysis; whilst falling head tests comprise the monitoring of the aquifer recovery to the instantaneous rise in water levels (in this case by introducing water into the bore).
** Considered outliers and not included in statistics.
+ permeable horizon limited to 60 to 70 m.
Average = geometric mean
MM = Marra Mamba Formation

A total of 79 estimates for aquifer permeability (k) relating to the identified hydrostratigraphic units have been derived from all studies to date. Permeability generally follows a log-normal distribution and estimates of mean permeability and the standard deviation have been derived for the log of permeability. Table 6.3 summarises the derived mean, maximum and minimum permeability values for each tested hydrostratigraphic unit, with the maximum and minimum values based on 90% confidence limits (assessed using the two-tailed Student's t-test); these values have been converted from the analysis on the log-normal distribution.

Table 6.3 Summary of Aquifer Permeability Values Derived from Testing

Hydrostratigraphic Unit	No. of Tests	Min k (m/d)	Mean k (m/d)	Max k (m/d)	Adopted k (m/d)
Upper Calcrete	13	6.29	10.34	17.00	10
Undifferentiated Tertiary	18	5.00	8.31	13.84	8
CID / Pisolite	10	8.85	14.04	22.26	14
Basal Crete	8	5.06	8.60	14.62	9
Altered MM: Unmineralised / Fractured MM	12	5.03	9.75	18.89	10
Altered MM: Ore	8	9.22	16.11	28.14	25*
WA Hardcap	6	12.77	21.48	36.12	20
Jeerinah (Fresh Jeerinah / MM)	4	0.014	0.017	0.021	0.01

*Updated based on model calibration to test pumping (Refer AQ2 2024)
Maximum and minimum values based on 90% confidence limits (assessed using the two-tailed Student's t-test)
MM = Marra Mamba Formation

6.3 Hydraulic Response During Pumping Tests

The pumping tests on the 2018/2019 production bores and recorded data at the associated monitoring bores also provided information with respect to the hydraulic connection of the hydrostratigraphic units. The key findings are summarised below:

- MDPB0011 - The drawdown and water quality data indicate hydraulic connection between the Tertiary and bedrock units at this location despite an interval of pisolitic clay underlying the pumped aquifer.
- MDPB0012 - The flattening of the drawdown curve for the pumped unit and increased rate of drawdown at MDPZ7449C after approximately 1000 minutes, indicated leakage from the Upper Calcrete through the underlying pisolitic clay.
- MDPB0013 – Results indicated much of the pumped water, when pumping from the Marra Mamba bedrock, is sourced from the overlying units, where the groundwater is less saline.
- MDPB0014 - Although most of the water abstracted from the pumping bore is sourced laterally from the Upper Calcrete unit, it also appears that the reduction in pressure from pumping allows up-coning of higher salinity groundwater at depth. This up-coning is insufficient to report to the pumping bore, although it is recorded in the deeper monitoring bore.
- MDPB0015 - The hydrostratigraphic units at this location grade into one another and it appears the entire Tertiary sequence, together with the underlying dolomite, are in hydraulic connection. The salinity of the pumped water suggests it is predominantly sourced laterally and from overlying units where the groundwater is less saline.

From the 2021 investigations, the installation and pumping test on MDPB0016 was specifically to assess the potential for the up-coning of saline water when pumping from the mineralised Marra Mamba in a proposed pit area. The salinity of the pumped water did not show an increasing trend during the constant

rate test (with salinity readings fluctuating between 3,400 and 3,500 µS/cm). However, as shown in Figure 6.7, salinity profiles for the pumped bore show increasing salinities at depth from before the step rate test (5660 µS/cm), before the constant rate test (7135 µS/cm) and after the constant rate test (8000 µS/cm), potentially indicative of the up-coning of the deeper, more saline groundwater.

Salinity profiles at the adjacent nested monitoring bores are also presented in Figure 6.7. No change in salinity is evident in the shallow monitoring bore (MDPZ7469C), whilst the intermediate monitoring bore (MDPZ7469B) shows a minor increase in salinity from 3,700 to 3,900 µS/cm from before and after the test pumping. The deep monitoring bore (MDPZ7469A) indicates an increase from 18,500 µS/cm before the step rate test to 18,900 µS/cm before the constant rate test and then a decrease in salinity to 17,900 µS/cm following the constant rate test. It is anticipated that the initial increase observed at the MDPZ7469A is probably the result of on-going recovery following the installation of MDPB0016 (rather than due to the short step rate test pumping), whilst the decrease in salinity resulting from the constant rate test may be attributable to the lateral flow of fresher groundwater towards test area.

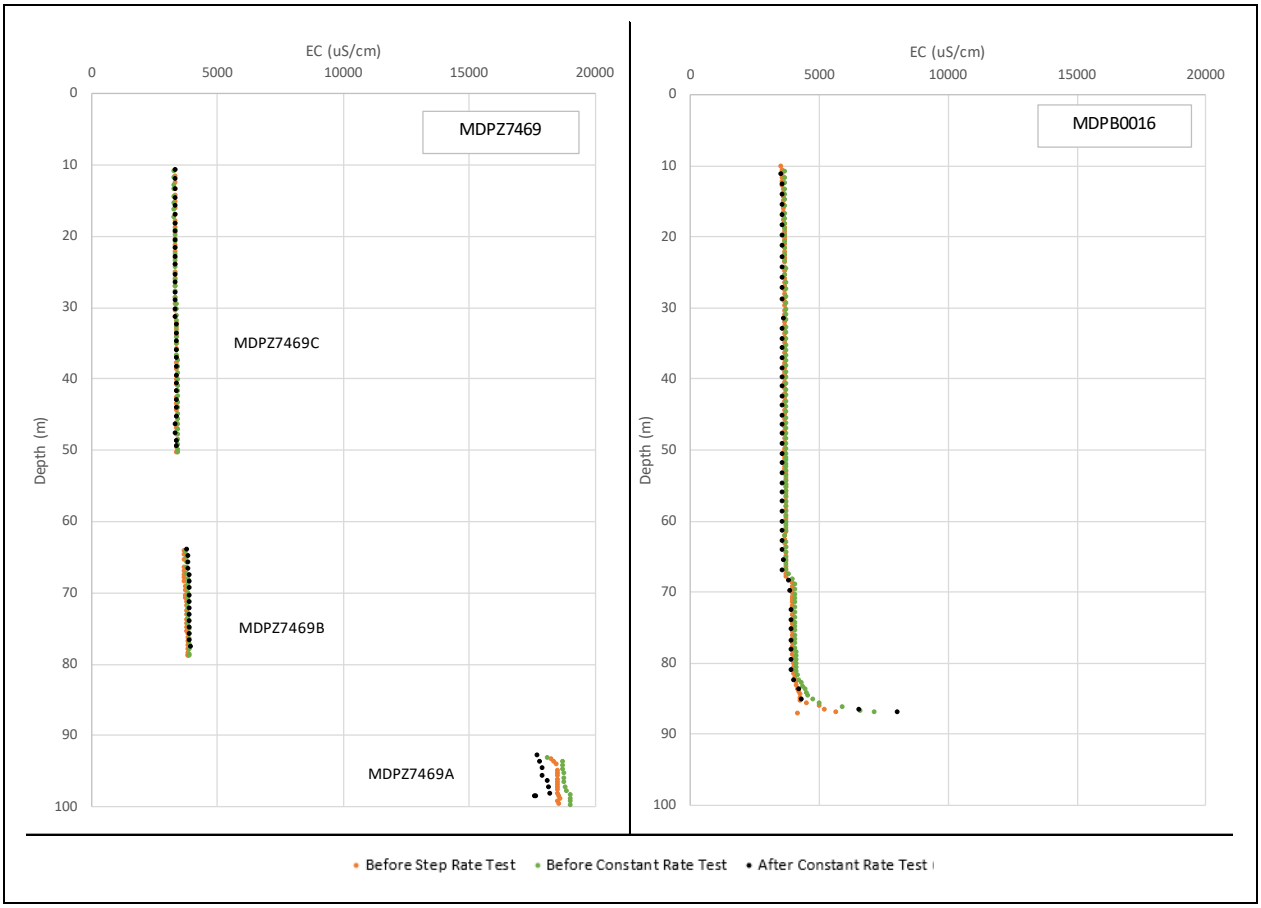


Figure 6.7 Salinity Profiles during the Pumping Test on MDPB0016

6.4 Groundwater Levels and Flow Direction

The surveyed bore collars and measured groundwater levels across the Study Area have been used to plot groundwater level contours (refer Figure 6.8 and Figure 6.9). Additionally, historical site water levels (measured at open mineral exploration holes during previous resource evaluation drilling programmes) and recorded water levels from DWER's database (together with NASA's Shuttle Radar Topography Mission (SRTM) data to set bore elevations) have been used to provide additional guidance to the contouring; noting that the SRTM data has been found to be inaccurate in this area, when compared to the bore survey data.

The water table elevation across the extended Study Area (inclusive of Mulga West) ranges between approximately 385 mRL and 420 mRL, The depth to groundwater In the Mulga East / Malay Well area, the hydraulic gradient is gentle across the lower lying areas, indicative of transmissive aquifers, and steepens along the northern boundary of the Study Area, indicative of lower permeability units (which is consistent with the presence of the Jeerinah Formation and fresh Marra Mamba aquitard). The transition from the Jeerinah aquitard to the Altered Marra Mamba aquifer may also be responsible for the abrupt bends observed in the groundwater contours in the northern Mulga East area (refer Figure 6.9). Hydraulic gradients also steepen down gradient of the Study Area, at the western end of Mulga West, indicative of a less transmissive setting, the narrowing of the valley and / or additional groundwater throughflow (from the Hamersley Ranges / Hamersley Gorge). Localised areas of minor groundwater mounding or potential preferential flow along more permeable structures may be present across the Mulga East orebody area, however, there is insufficient geological and hydrogeological data to validate this concept.

The depth to groundwater is presented in Figure 6.10. This has been derived from available LiDAR data and the contoured groundwater level surface for December 2021 (Figure 6.8). In the Mulga East / Malay Well area the depth to groundwater is shallow in the lower lying, valley areas at approximately 3 and 5 mbgl and increases with elevation, to depths of up to 45 mbgl (at MDPZ7467) in the more elevated areas (i.e. to the north of the inferred resource area). Although no drilling has taken place on the claypans and at the channel pools due to the environmental and cultural heritage significance of these areas, the derived depth to water (i.e. Figure 6.10) indicate these features are not groundwater-related. Further discussion regarding the conceptualisation of the claypans is presented in Sections 4 and 10.

In assessing the vertical gradients between adjacent bores installed at different depths (i.e. the clustered and paired bores), only the manual piezometric measurements (taken after bore installation and during each monitoring round) have been considered due to the potential variations in accuracy with the different depth ratings of pressure transducers. The majority of bores show minimal differences in piezometric head indicating hydraulic connection between the measured overlying / underlying units.

Vertical gradients are only evident at seven cluster bore locations from the 2018/2019 field programme (MDPZ7449, 7451, 7457, 7460, 7462, 7469 and 7471) where the screened units of the bores are separated by an intervening low permeability material, with thicknesses ranging between 2 and 30 m. The distribution of vertical hydraulic gradients within the sequence varies spatially although without any specific trend or distribution. This is believed to be a result of the variable distribution of permeability within the Tertiary deposits.

Only two paired monitoring bore completions were installed during the 2021 drilling programme (MDPZ9212D & S and MDPZ9215D & S) and both locations show downward hydraulic gradients. The collars of the 2023 bores have yet to be surveyed to accurately assess vertical gradients.

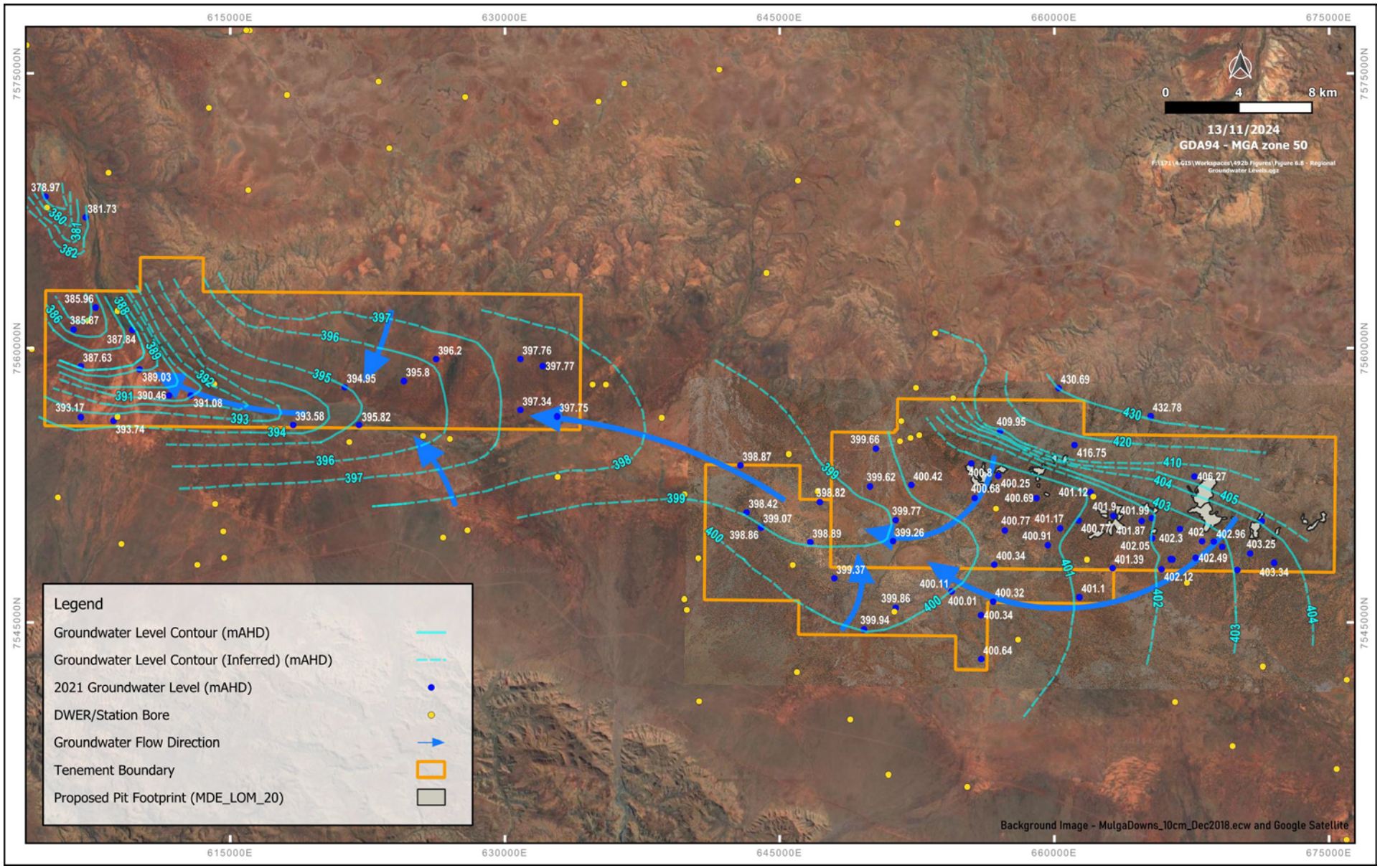


Figure 6.8 Regional Groundwater Level Contours (December 2021)

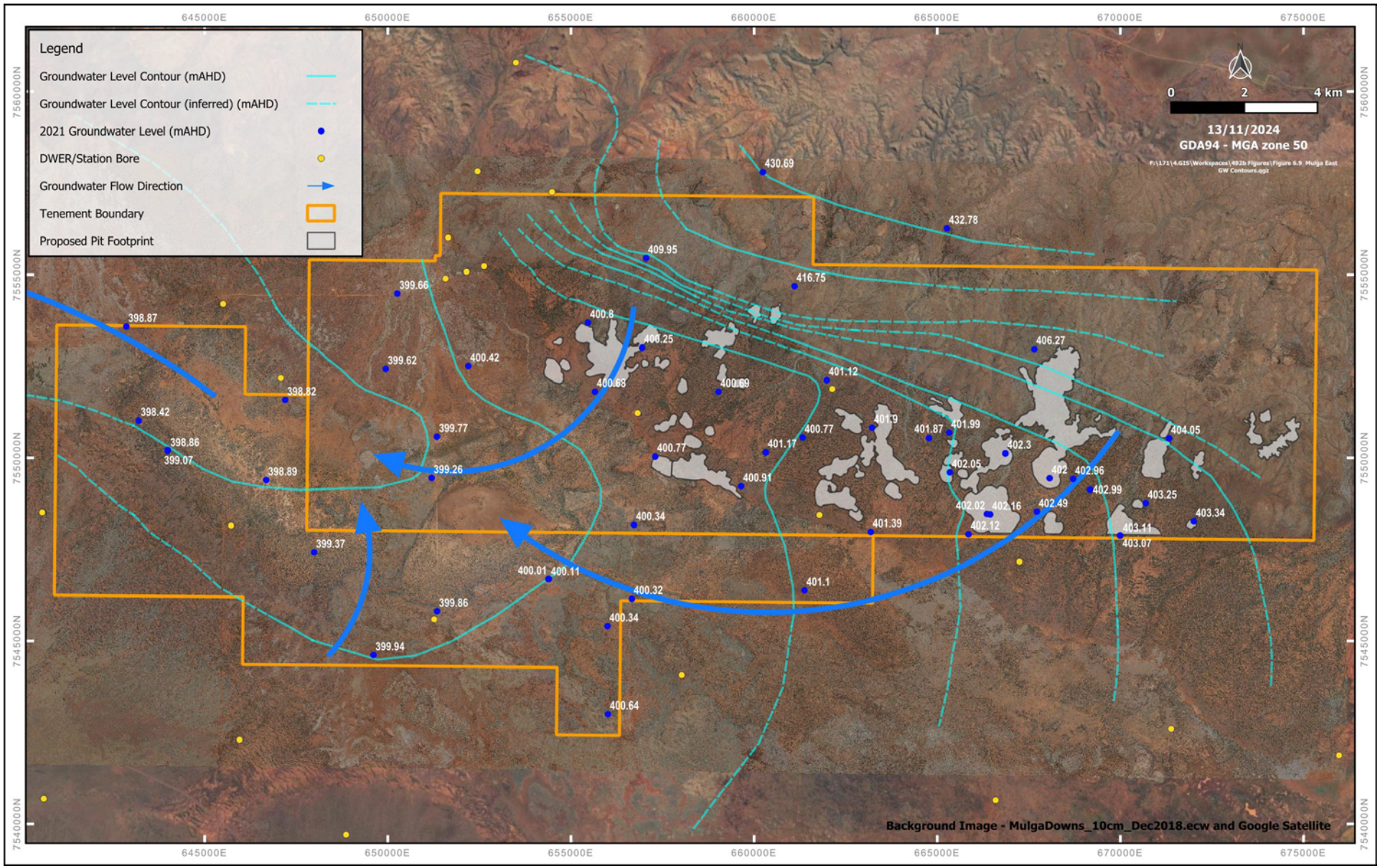


Figure 6.9 Groundwater Level Contours across Mulga East & Malay Well (December 2021)

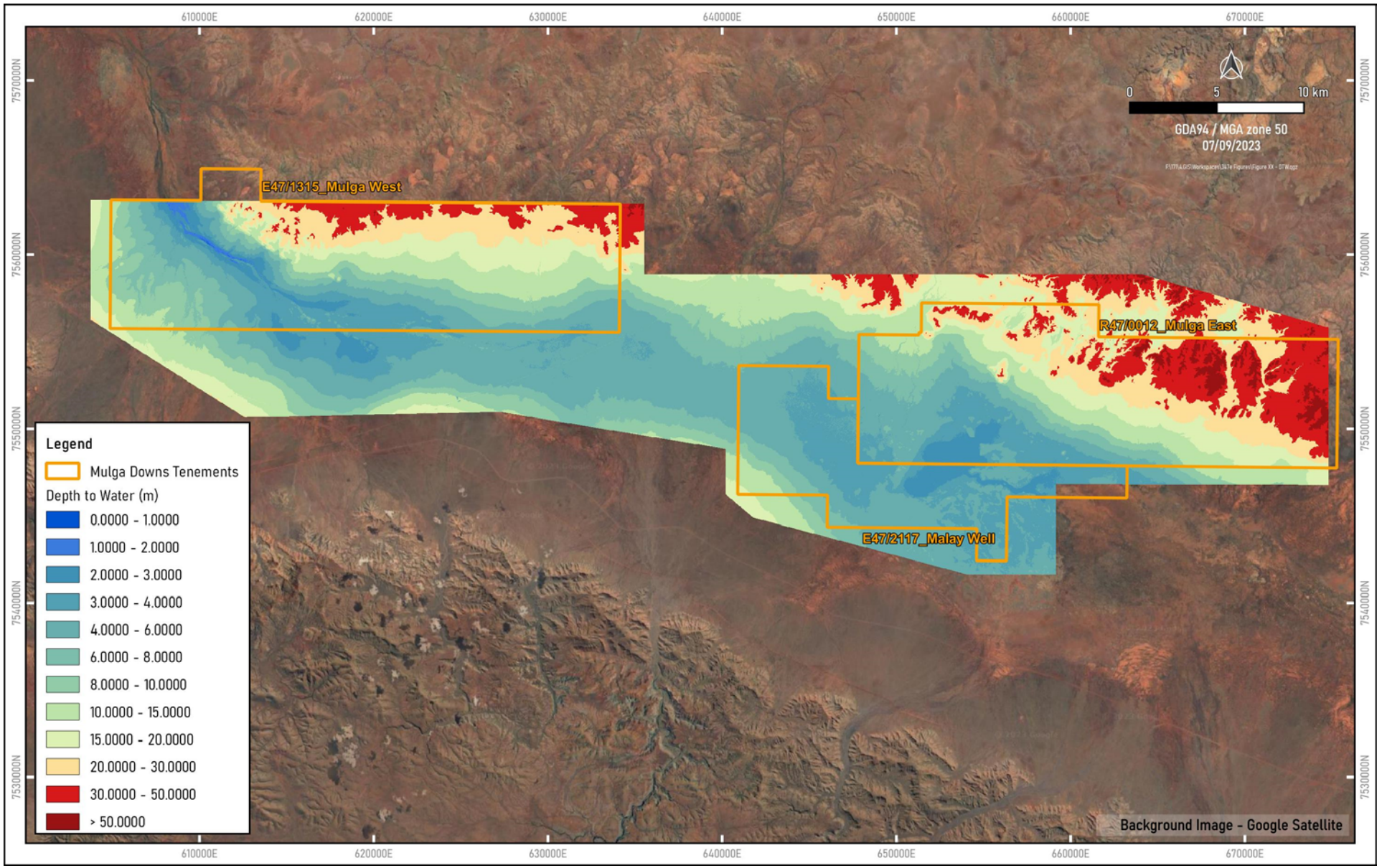


Figure 6.10 Regional Depth to Groundwater (December 2021)

6.5 Groundwater Level Changes

The time-series water level data for bores near to cross-sections B, C and D (refer Figure 6.5 for locations) are presented in hydrographs in Figure 6.11 to Figure 6.13, with hydrographs for the Fridge Hill and Horseshoe Hill areas presented in Figure 6.14 and Figure 6.15 respectively. In addition, Figure 6.16, Figure 6.17 and Figure 6.18 present hydrographs for the Koodjeepindarranna Claypan, Gnalka Gnoona Claypan and Mulga West areas respectively. The following salient observations can be made:

- All bores show varying responses to the rainfall events that have occurred over the monitoring period from January 2019 to November 2023. However, there has not been a significant cyclonic rainfall event during the monitoring period to observe the associated groundwater responses.
- Despite the seasonal fluctuations, all bores show an overall declining trend in water levels over the monitoring period.
- Bores MDPZ7454, 7455, 7466 and 7467, installed in low permeability Marra Mamba and / or Jeerinah Formations on the upper slopes, show a subdued and delayed response to the rainfall events, with only minimal seasonal fluctuation at MDPZ7466 and 7467, in the Fridge Hill / Horseshoe areas.
- Bore MDPZ7459, a shallow bore (20 m deep) in the northern alluvial fan between the two claypans, shows a significant but delayed response to the rainfall events.
- A declining trend in water levels is generally evident at all bores following the 2020/21 wet season, however, many bores show a rapid response to the small November / December 2021 rainfall event. Bores presenting this response are screened against either bedrock or the deeper Tertiary units (i.e. Basal Crete or CID), whilst adjacent bores installed in Upper Calcrete and / or the Undifferentiated Tertiary units, continue to show a declining trend. This suggests recharge to the deeper units.
- In the Gnalka Gnoona Claypan area (Figure 6.18), the bores show a prolonged period of elevated water levels following the rainfall events during the first half of 2022. This is anticipated to be due to on-going seepage from the ponded water in the claypan.
- At bore MDPZ7471, near the Koodjeepindarranna Claypan, an upward flow gradient is evident through the dry season, whilst manual water level readings in May 2020 indicate a downward flow gradient following the 2019/20 wet season. Although the deeper bores at this location show a rapid response to the December 2021 rainfall event, the 2019/20 data indicates the shallow bore (in the Upper Calcrete) has a greater overall response to the wet season recharge, resulting in the change to a downward gradient. This is consistent with a loss of water from the claypans as seepage to groundwater, however, a similar response is not evident in the 2022-2023 dataset. The same change in hydraulic gradient appears to be evident at MDPZ7462, however, data at this location are limited due to the restricted access to this site.

Longer-term water level data (between December 2008 and December 2021) are available for several monitoring bores across the orebody area and are presented in Figure 6.19, with bore locations shown in Figure 6.20. Although bore completion logs are not available, these mineral exploration holes are cased with 25 mm PVC, with slotted casing assumed to be installed from the water table to total depth.

The long-term hydrographs for these bores show groundwater recession with very limited seasonal response during the period late 2008 to late 2010 when annual rainfall totals were lower (i.e. 316 mm, 325 mm and 231 mm in 2008, 2009 and 2010 respectively, compared to 395 mm in 2018). Thereafter (2011 to 2021), seasonal responses have ranged between ~0.2 and 1.5 m with the latter in response to a cyclonic event in January 2012. The data sets provide valuable baseline data, however, each of these sites will be affected by the proposed mine dewatering operations due to their proximity to the proposed pit locations therefore there are no longer-term data sets (i.e. commencing earlier than 2019) outside of the impact zone.

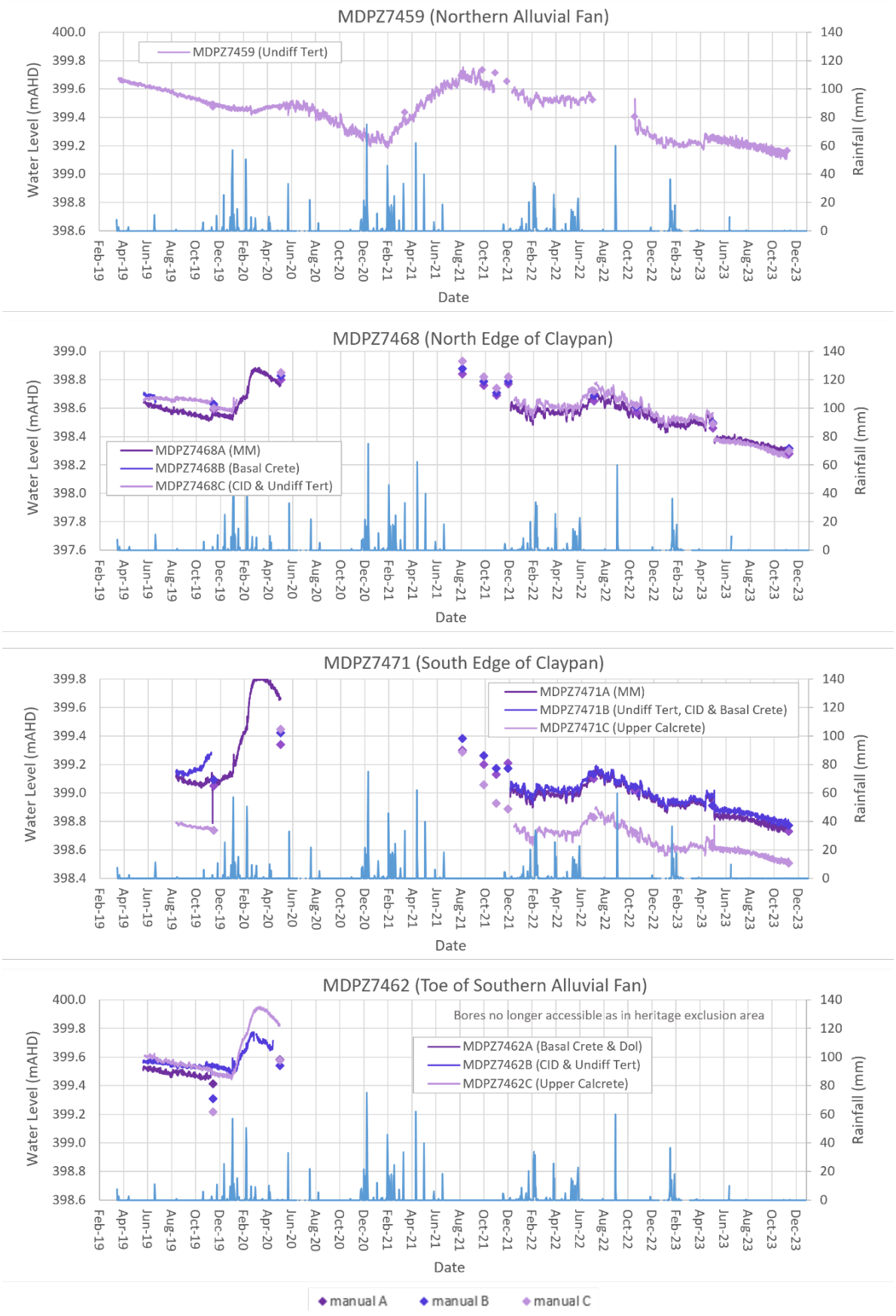


Figure 6.11 Section B Groundwater Level Hydrographs

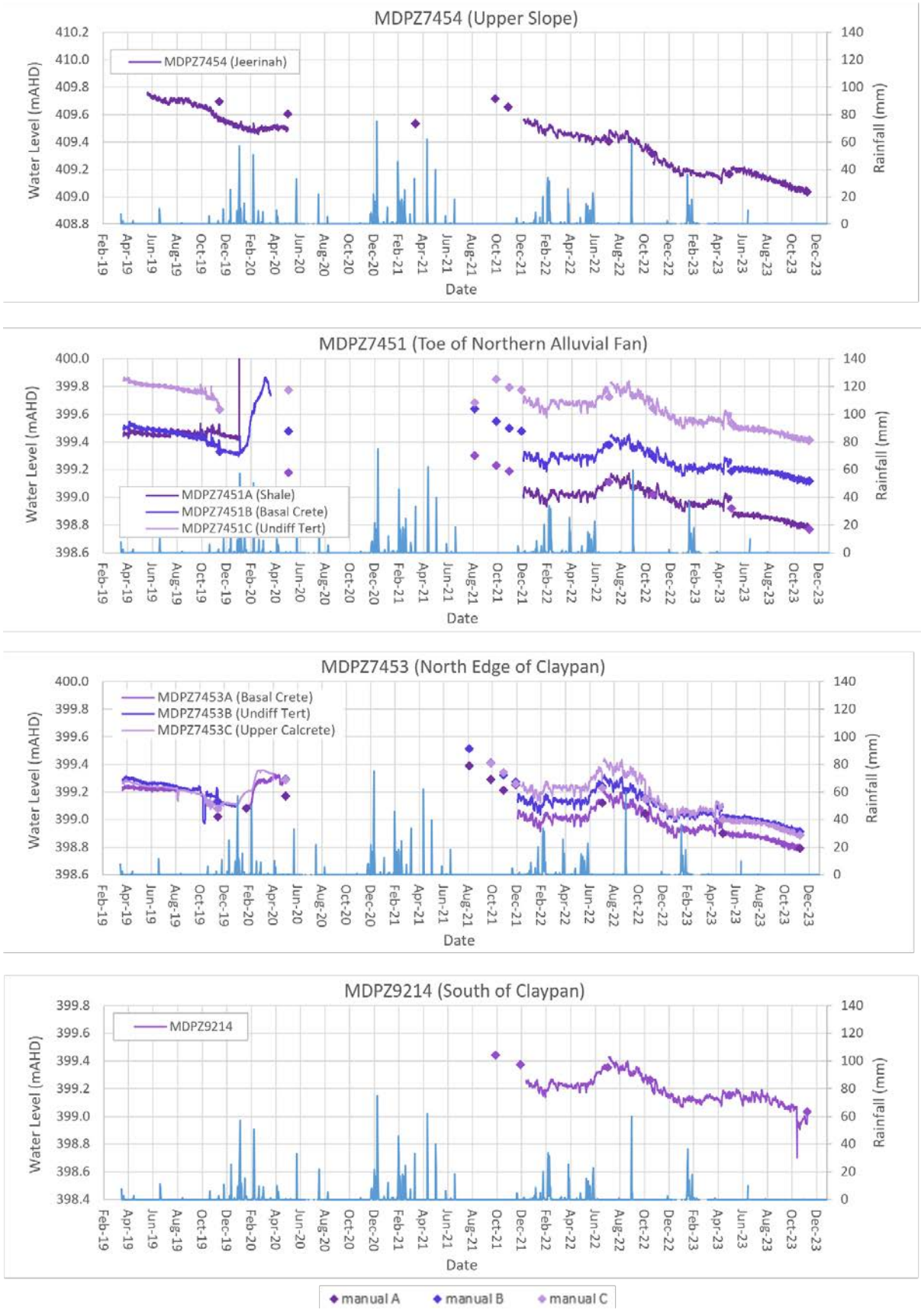


Figure 6.12 Section C Groundwater Level Hydrographs

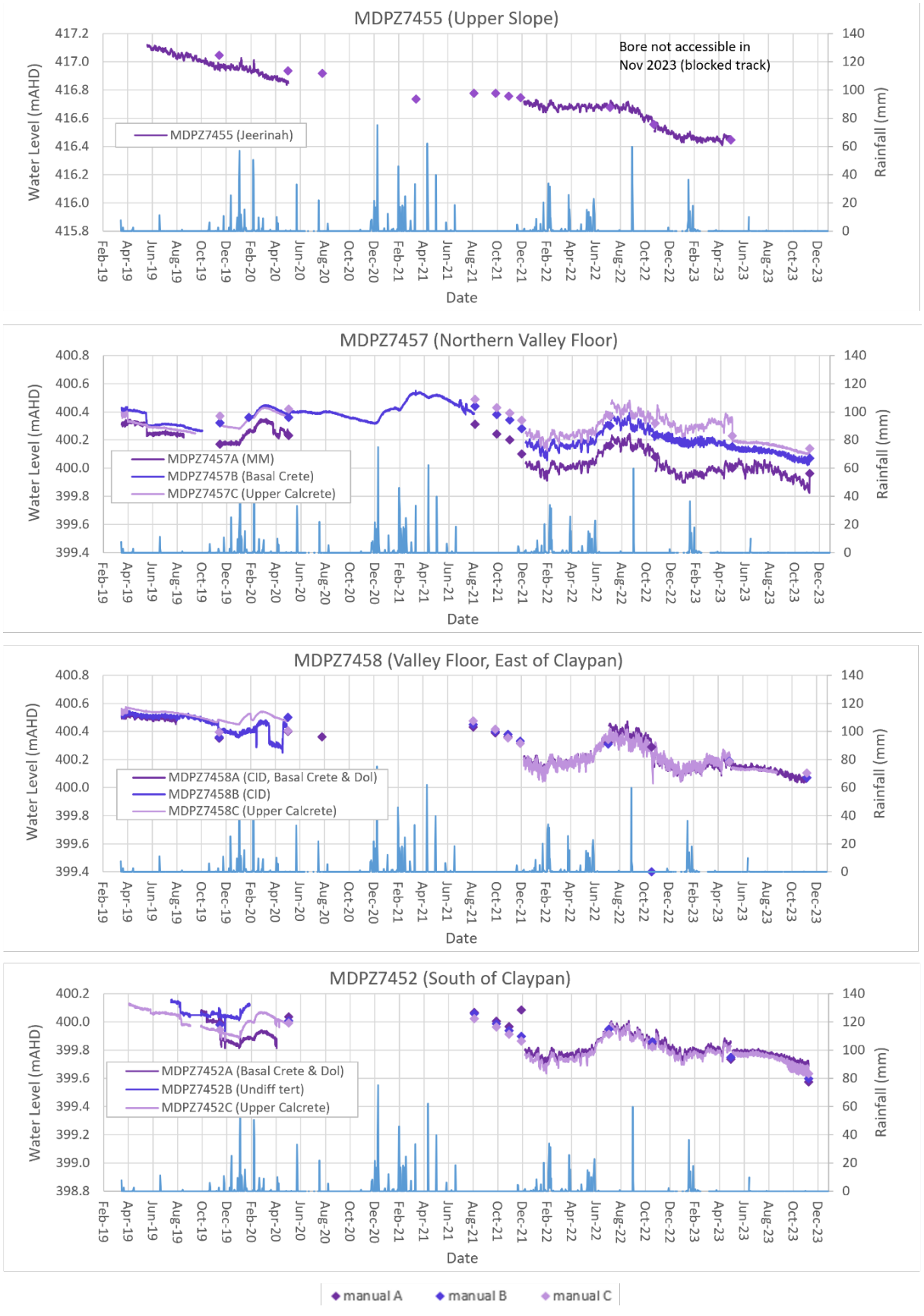


Figure 6.13 Section D Groundwater Level Hydrographs

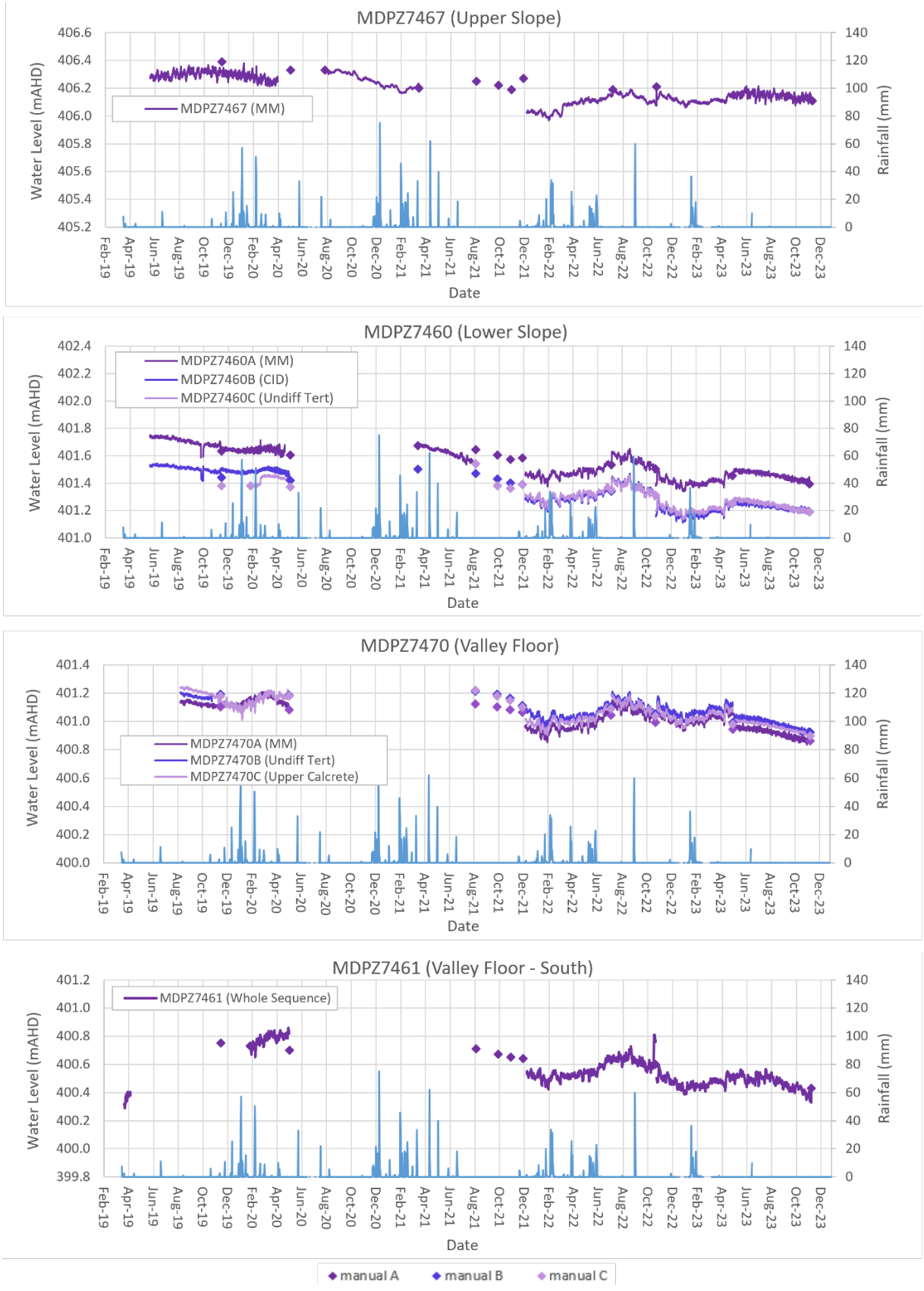


Figure 6.14 Groundwater Level Hydrographs for Extended Fridge Hill Area

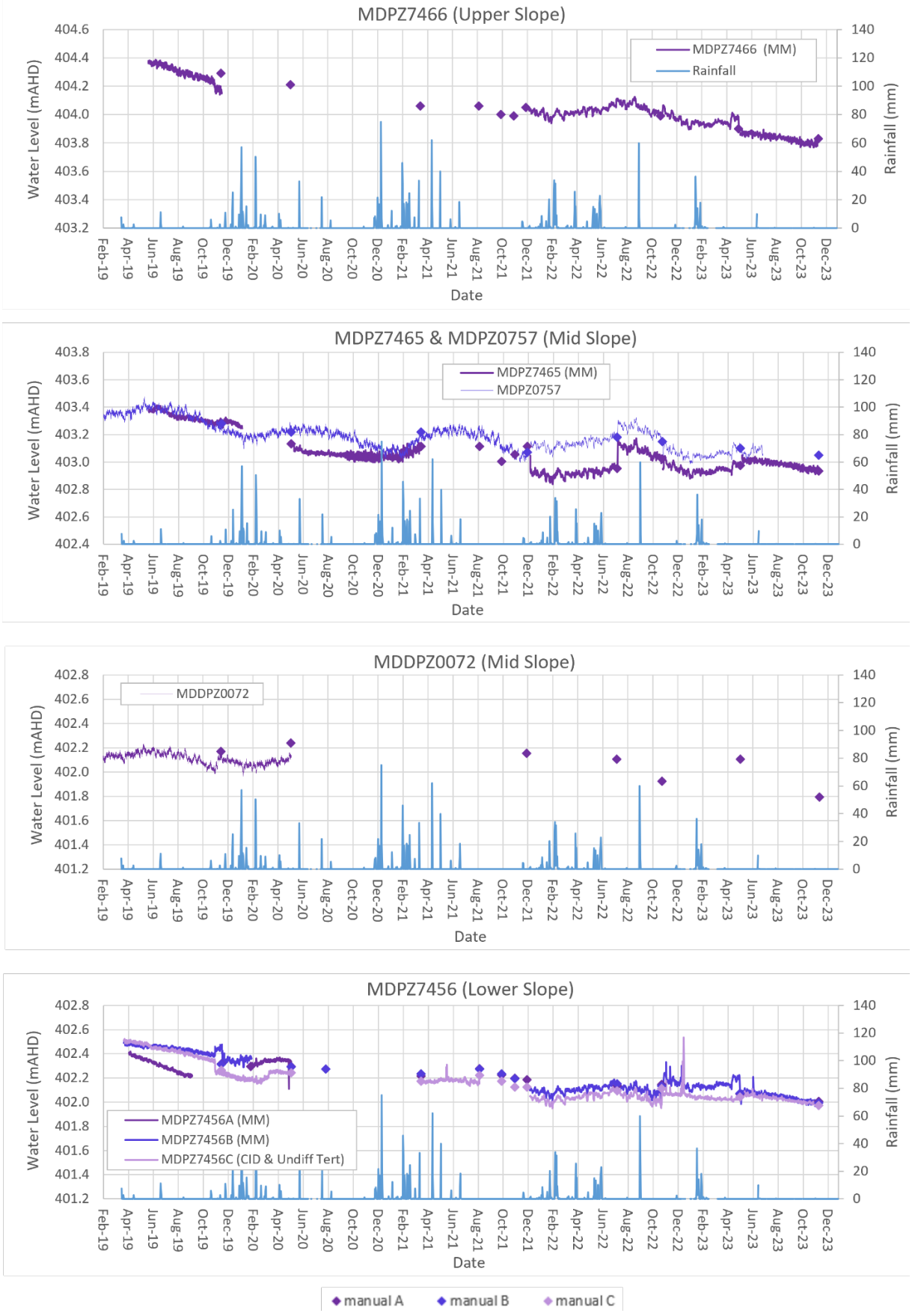


Figure 6.15 Groundwater Level Hydrographs for the Horseshoe Hill Area

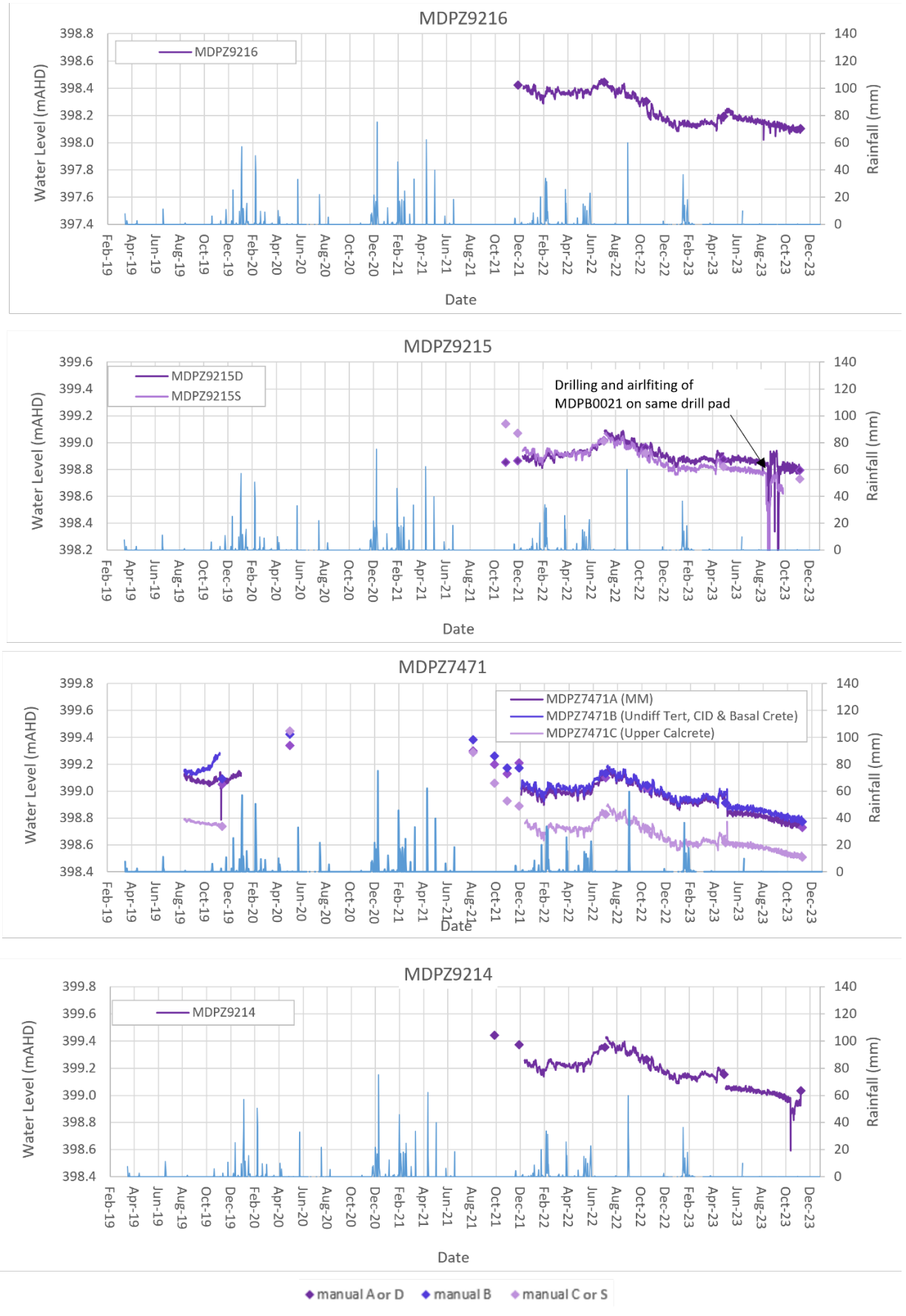


Figure 6.16 Groundwater Level Hydrographs for the Koodjeepindarranna Claypan Area

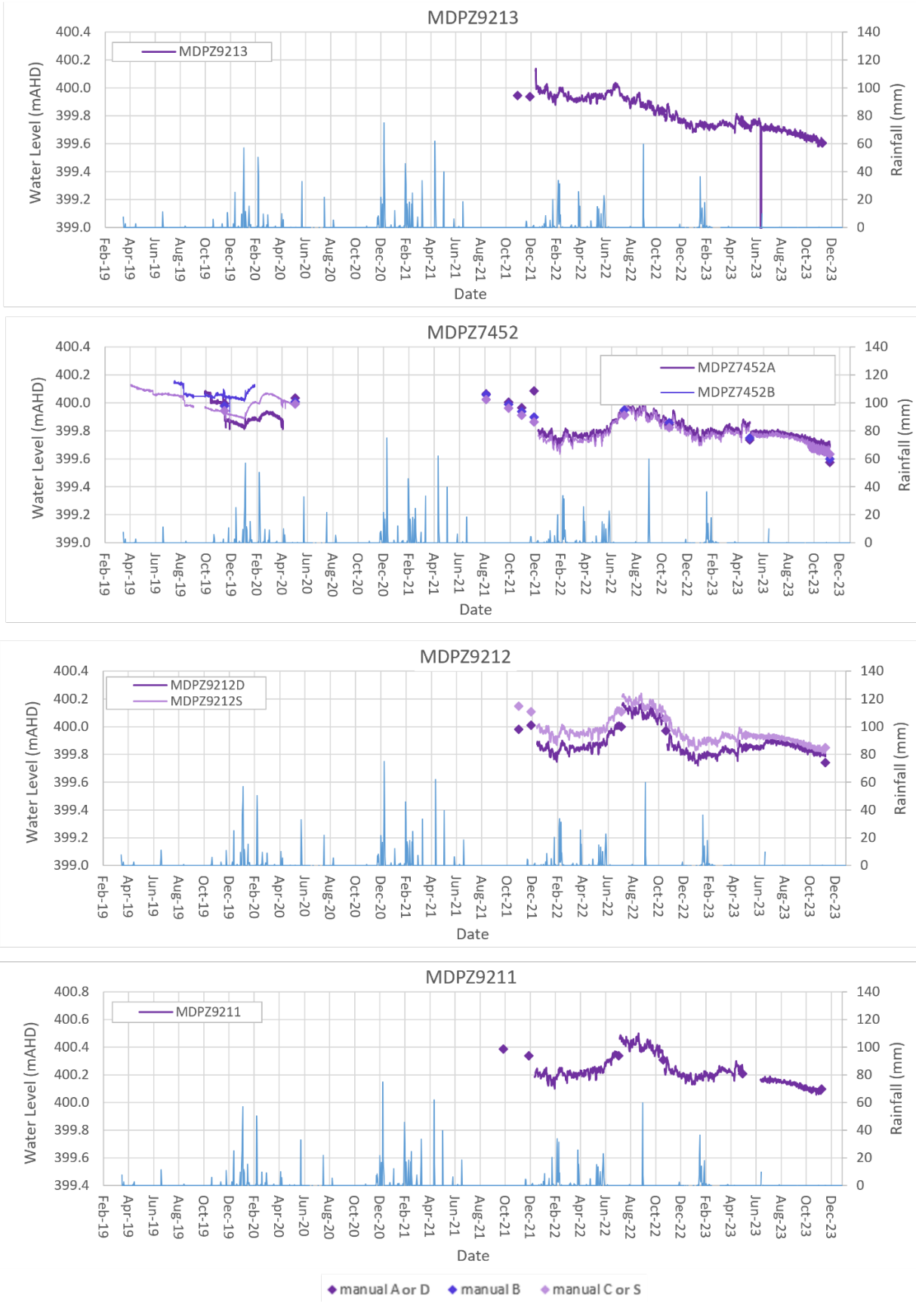
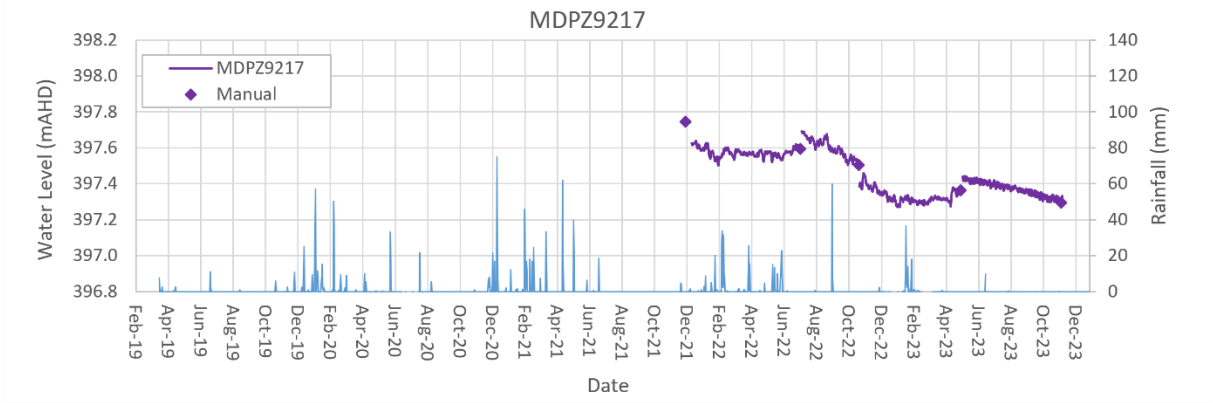
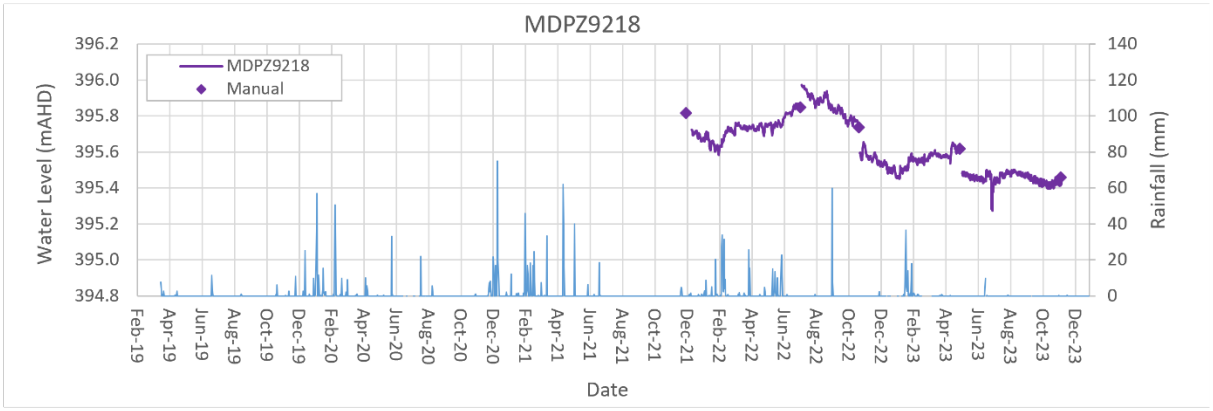
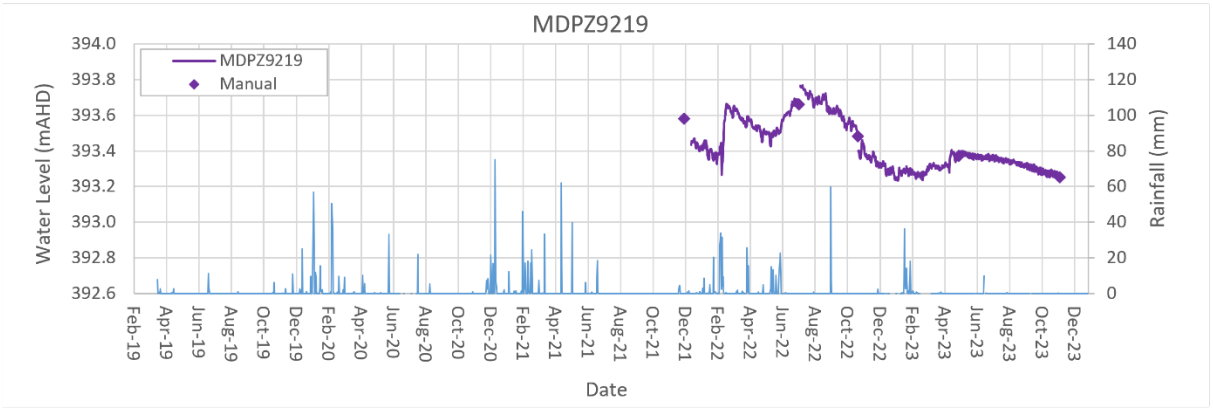
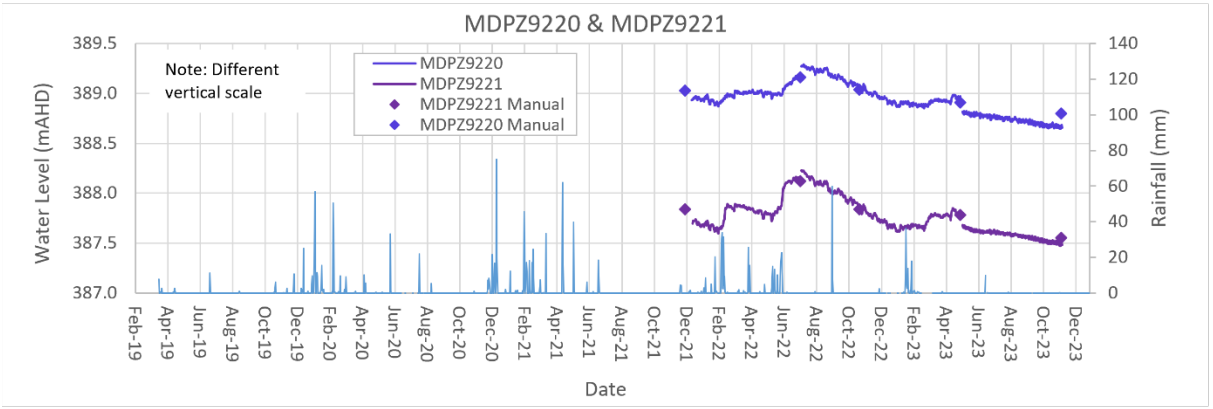


Figure 6.17 Groundwater Level Hydrographs for the Gnalka Gnoona Claypan Area









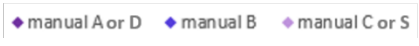


Figure 6.18 Groundwater Level Hydrographs for Mulga West

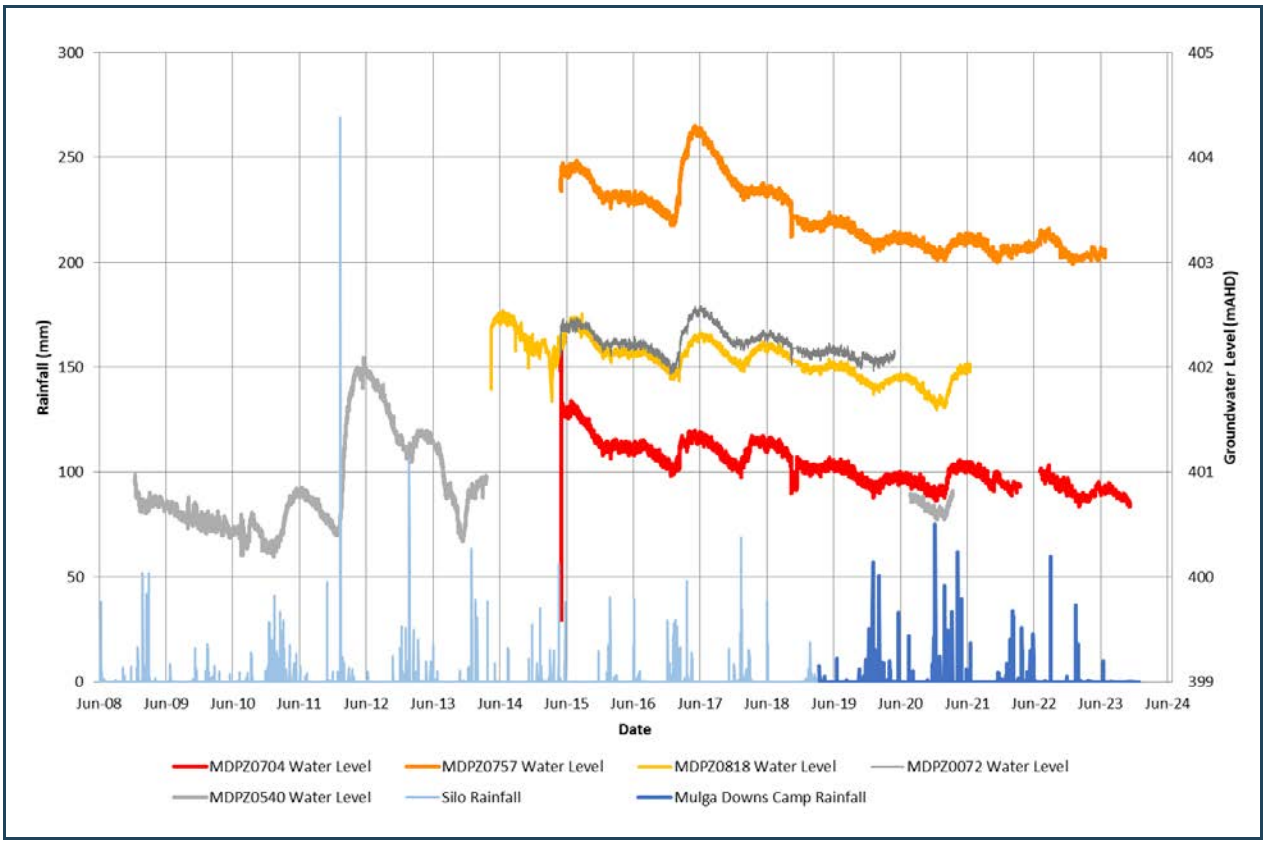


Figure 6.19 Long-term Groundwater Level Hydrographs

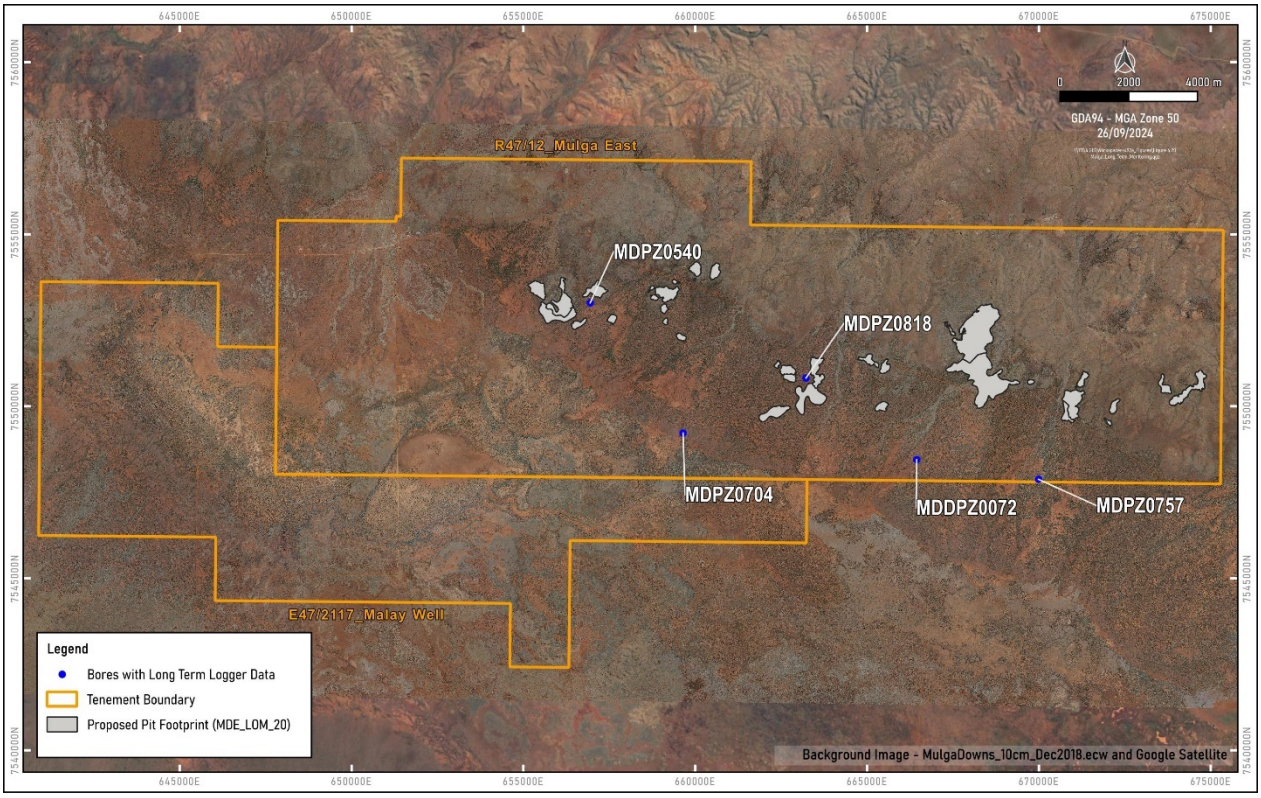


Figure 6.20 Bore Locations for Long-term Groundwater Level Hydrographs

6.6 Groundwater Quality

Groundwater quality data for the Study Area are available from the analysis of water samples, from field readings of salinity during drilling, salinity profiling and some time series data from the installed LTC loggers.

All hydrochemical data from the 2018 to 2023 bore installation programmes and baseline monitoring to November 2023 is presented in Appendix G.

As the shallow groundwater within the Study Area is used for station bores, the hydrochemical data recorded to date have been compared against livestock drinking water guidelines (ANZECC & ARMCANZ 2000), with a summary provided in Table 6.4. Exceedances of aluminium, fluoride and mercury have been recorded at bores where the groundwater salinity is within the preferable drinking water limits for beef cattle (i.e. <5,000 mg/l).

The groundwater across the Study Area ranges from fresh to saline and is generally slightly acidic to slightly alkaline. Concentrations of total dissolved solids (TDS) range from 180 mg/L (EC 300 µS/cm) in the upper reaches of the groundwater system to 17,000 mg/L (EC 23,000 µS/cm) in the valley area. The pH of the groundwater generally ranges between 5.9 and 8.2, however, in the northeastern most bores, the groundwater seems to be more acidic with values of pH 4.0 and 4.4 recorded at depth at bores MDPZ7466 and MDPZ7467 and pH 3.6 recorded at MDPZ7455. These low pH values are anticipated to be a result of the oxidation of sulphides in the Jeerinah Formation, with oxygenated groundwater flowing through minor local fractures. This is consistent with observations elsewhere in the Pilbara, for example on the Wonmunna Plateau adjacent to the West Angelas mine.

All hydrochemical data from bore installation programmes and baseline monitoring rounds are tabulated in Appendix G and plotted on Expanded Durov Diagrams in Appendix J. The Mulga East / Malay Well hydrochemical data from the most recent monitoring round (November 2023) have been plotted on an Expanded Durov Diagram in Figure 6.21 with all (2019 to 2023) Mulga West hydrochemical data plotted in Figure 6.22. Plotted data show that the groundwater in the Study Area can be categorised into several different water types, with generally little change in the water types between the collected water samples over the baseline monitoring period (refer water types versus time summary in Appendix J). Figure 6.23 shows where these various water types occur spatially; salient points are as follows:

- Bicarbonate dominant groundwater (Water Types 1 and 2) occur at shallow depths at MDPZ7459 and at times at MDPZ7450C, indicative of recharge waters in the vicinity of an alluvial fan in the northeast of the Study Area. The most recent shallow sample from nearby bore MDPZ7464 plots as a Type 3, again indicative of the influence of recharge waters.
- Groundwater across the majority of the Mulga East orebody area, and to the north, predominantly has no dominant cations or anions, indicative of potential mixing of several groundwater types and / or some dissolution / ion exchange (on the clay fraction) during recharge or aquifer residency (Water Types 5 and 6). This groundwater type is also present to the south of the claypan / valley area (at MDPZ9213 and MDPZ9225) and on the northern side of the valley in Mulga West (at MD5461, MD5455, MD6605 and MD5382).
- Groundwater down gradient of the Mulga East orebodies, in the valley area, is generally chloride and sodium dominant (Water Type 9) indicative of an end point ("older") water, suggesting the groundwater has been subjected to evapotranspiration and / or mineral dissolution since it was recharged, or it has been affected by the leaching of salts through the unsaturated zones underlying the claypan areas. This groundwater type extends down-gradient from the claypans and is evident along the Fortescue Valley in Mulga West (at bores MDPZ9217 to MDPZ9221); in this area, the groundwater may also be affected by the leaching of salts evident on the riverbanks.

- Groundwater at MDPZ7466 (shallow) and, at times, at MDPZ7465, on the eastern edge of the Study Area, and at MDPZ7499C (November 2019) and MDPB0012 (at installation), in the Malay Well orebody area, are chloride dominant with no dominant cation (Water Type 8), indicative of the reverse ion exchange of a sodium chloride dominant water. This is likely to have occurred on clay-rich facies in the Tertiary Detritals (as were encountered in bores MDPZ7499C and MDPB0012 fin TD2 / TD3) or weathered shale (as was encountered in bores MDPZ7465 and MDPZ7466).
- The water type at MDPZ7450C has been variable over the monitoring period. The initial sample (in May 2019) was Type 2, thereafter Type 6 (November 2019 and March 2021) and Type 3 (May 2020 and December 2021); the latter indicative of the influence of recharge. More recently (May and November 2023) sampled water is Type 8, indicative of the reverse ion exchange within the Tertiary Detritals.

Table 6.4 Summary of Baseline Groundwater Quality Results Compared to Livestock Drinking Water Guidelines (ANZECC & ARMCANZ 2000)

	Preferable Range / Limit (mg/L)	Trigger Range / Value (mg/L)	Maximum in Study Area (mg/L)	Valley Area (mg/L)	Valley Flanks (mg/L)	Upper Slopes (mg/L)	Comment
TDS#	0 to 5,000*	5,000 to 10,000**	18,000	1,200 to 18,000	300 to 16,000	180 to 1,400	Exceedances at many bores in vicinity of the claypans and at depth on the valley flanks
Calcium		1,000	700	42 to 530	22 to 700	7.1 to 170	
Nitrate	400	1,500	51	<0.01 to 33	0.01 to 51	<0.01 to 23	
Nitrite		30	5.3	0.012 to 5.3	<0.005 to 0.16	<0.05	
Sulfate	1,000	2,000	4,200	230 to 4,200	3 to 3,400	13 to 720	Exceedances in many deep and intermediate bores in the valley and flank areas. < 1,000 mg/L at all shallow bores except the following valley area bores: >1,000 mg/L at MDPZ7449C, MDPZ7458C, MDPZ7468C & MDPZ9212S; >2,000 mg/L at MDPZ7452C & MDPZ7453C (max: 2,700 mg/L)
Aluminium		5	9.6	<0.005 to 0.15	<0.005 to 0.31	<0.005 to 9.6	Exceedances at MDPZ7455 & MDPZ7466 (Upper Slopes) Several bores with Total Aluminium exceeding the trigger value, but only in May 2020.
Arsenic	0.5	5	0.033	<0.001 to 0.025	<0.001 to 0.021	0.015 to 0.033	
Boron		5	5	0.26 to 5	0.19 to 4.4	0.15 to 0.75	Exceedances at MDPZ7451A (valley area)
Cadmium		0.01	0.0021	<0.0001 to 0.0011	<0.001 to 0.0020	0.0001 to 0.0021	
Chromium		1	0.025	<0.001 to 0.025	<0.001 to 0.016	<0.001	
Cobolt		1	0.098	<0.001 to 0.098	<0.001 to 0.014	<0.001 to 0.059	
Copper		1	0.016	<0.001 to 0.002	<0.001 to 0.016	<0.001 to 0.013	
Fluoride		2	11	0.6 to 11	0.2 to 2.8	0.2 to 1.3	Exceedances (2 to 3.5 mg/L) at many bores (predominantly in the valley); those with TDS <5,000 mg/L include: MDPZ7470B, MDPZ7470C, MDPZ9217 11 mg/L at MDPZ7458C (one sample)
Lead		0.1	0.005	<0.001 to < 0.005	<0.001 to 0.005	<0.001 to 0.003	
Mercury		0.002	0.0043	<0.0002 to 0.012	<0.0002 to 0.0043	<0.0001 to <0.002	Exceedances at MDPZ7451C, MDPZ7453A (valley area) & MD6605 Lower (Mulga West valley flank). 0.002 mg/L at MDPZ7452A & MDPZ7452B (valley area)
Molybdenum		0.15	0.025	<0.001 to 0.025	<0.001 to 0.009	<0.0001 to <0.005	
Nickel		1	0.22	<0.001 to 0.22	<0.001 to 0.04	<0.002 to 0.12	
Zinc		20	0.51	0.006 to 0.24	<0.005 to 0.51	0.034 to 0.51	

Valley Area = area of Type 9 groundwater (refer Figure 6.23); Valley Flanks = area generally covered by Types 5 & 6 groundwater (refer Figure 6.23); Upper Slopes = Bores in fresh Jeerinah Fm (MDPZ7454, MDPZ7455, MDPZ7466 & MDPZ7467)

Bold indicates bores with groundwater salinity <5,000 mg/L TDS

Recommended TDS Concentrations for Beef Cattle

*TDS of 4,000 to 5,000 mg/L: Animals may have an initial reluctance to drink or there may be some scouring, but stock should adapt without loss of production.

** Loss of production and a decline in animal condition and health would be expected. Stock may tolerate these levels for short periods if introduced gradually.

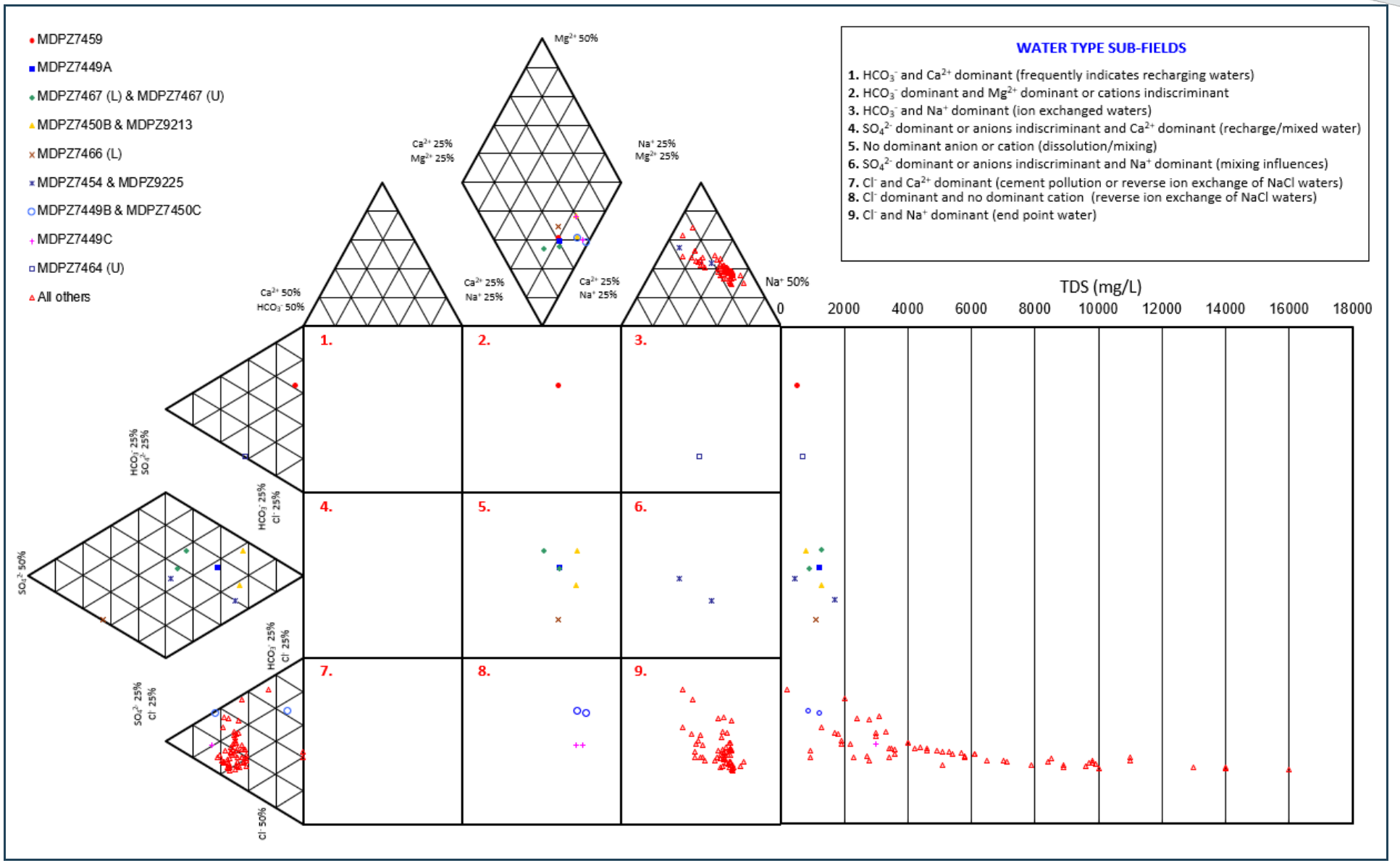


Figure 6.21 Mulga East / Malay Well Expanded Durov Diagram (Baseline Data Nov 2023)

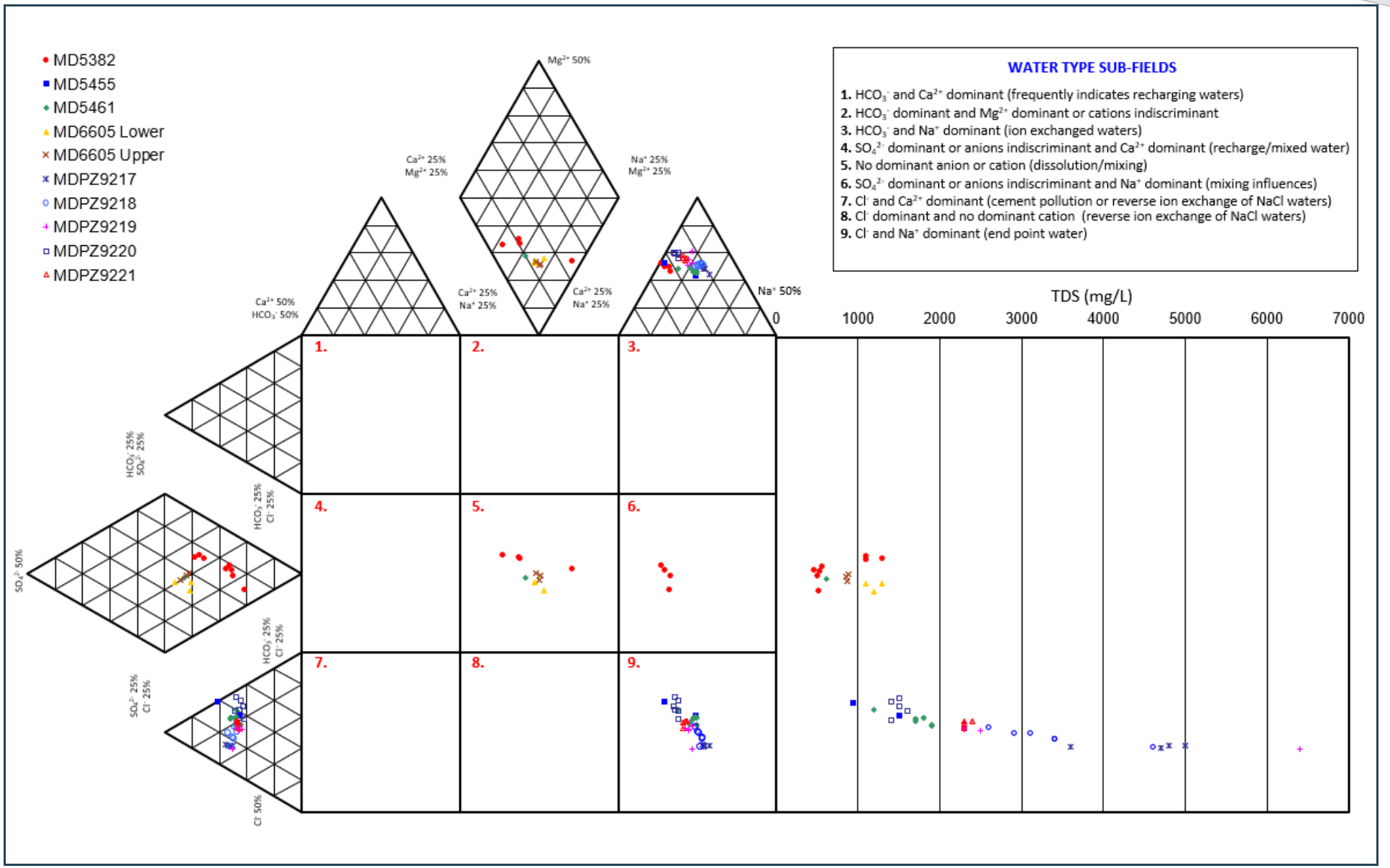


Figure 6.22 Mulga West Expanded Durov Diagram (Baseline Data Aug 2019 to Nov 2023)

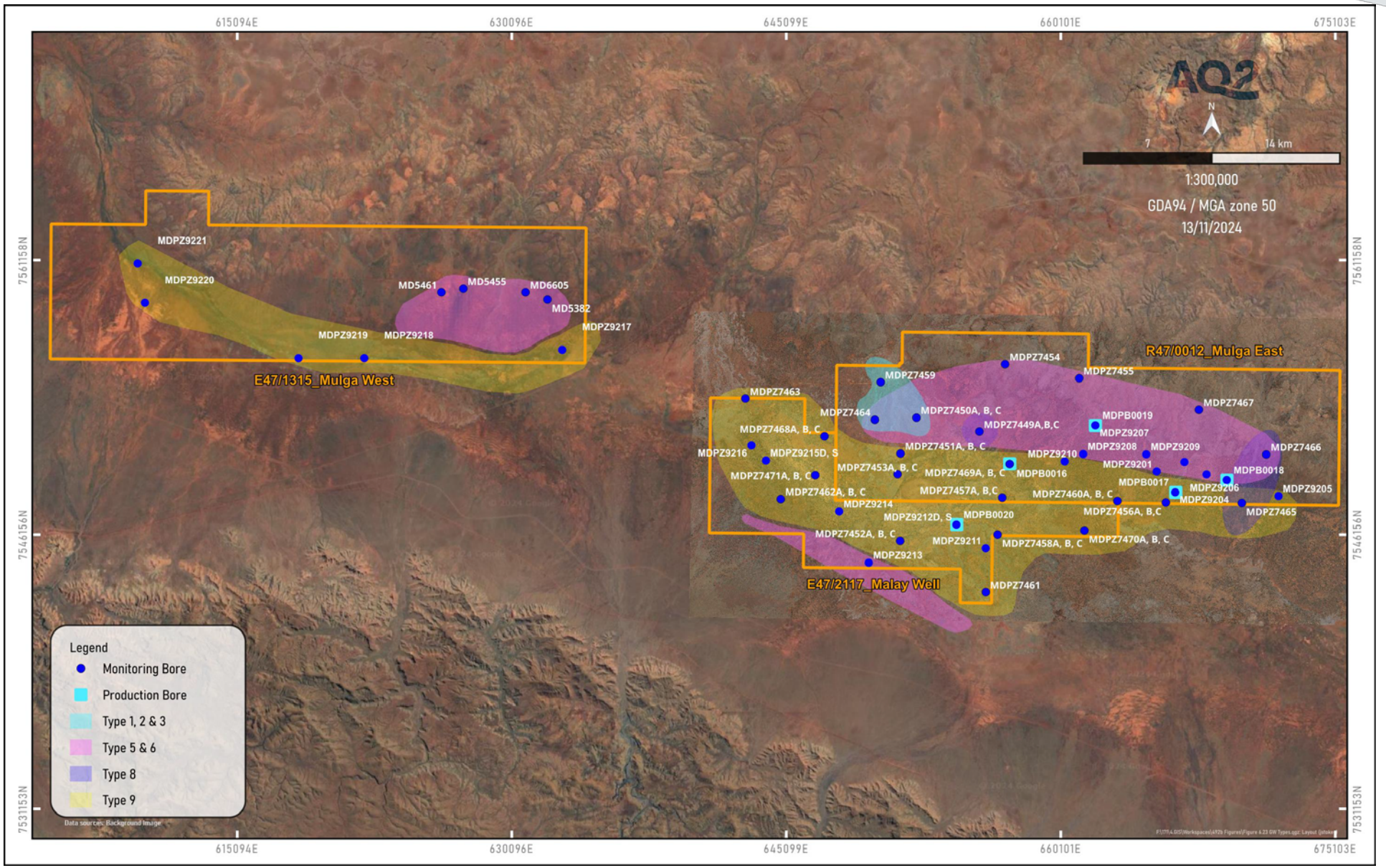


Figure 6.23 Groundwater Types

All static salinity data for each bore at installation and from each monitoring round have been compiled and are presented in Appendix H. It should be noted that salinity profiles have only been plotted for the intervals that are representative of the in-situ mobile groundwater within the screened interval of the bore. Additionally, for paired (deep and shallow) and cluster (deep, intermediate and shallow) monitoring bores, the salinity profiles for each bore have been combined into one profile. Key observations from these salinity plots and those compiled for the baseline monitoring as are as follows:

- The salinity profiles for the shallower and / or higher elevation bores along the northern boundary of the Study Area (i.e. single monitoring bores MDPZ7459 (5 to 28 mbgl), MDPZ7454 (27 to 58 mbgl) and MDPZ7455 (32 to 60 mbgl)) show no change in salinity with depth and are fresh throughout the profiles.
- Where changes in salinity with depth are evident, the salinity generally increases with depth, however, exceptions are as follows:
    - MDPZ7449 (cluster bores) where both salinity profile and laboratory data indicate the groundwater between 5 and 11 mbgl has a salinity of between ~6,000 and 11,000 µS/cm, whilst below this the salinity is ~2,000 µS/cm. However, an EC reading of 1,480 µS/cm was recorded for the drilling discharge water at 8 mbgl. The reason for this localised occurrence of shallow, saline groundwater is uncertain.
    - MDPZ7456 (cluster bores) where a very minor decrease in salinity is evident from the salinity profiles between ~60 and 100 mbgl.
    - MDPZ9204 and adjacent production bore MDPB0017 where a very minor decrease in salinity is evident from the salinity profiles between ~70 and 94 mbgl. The changes in salinity in MDPZ9204 between 19 and 44 mbgl is not evident in MDPB0017 and is thought to be remanent of changes resulting from the drilling and bore airlift development.
    - MDPZ7458 (cluster bores) where the salinity profiles indicate the groundwater salinity increases from ~15,000 to ~18,000 µS/cm at ~35 mbgl for a depth of between 5 and 18 m. This is coincident with a zone of vuggy, high permeability calcrete (at the base of the Upper Calcrete) and underlying pisolite.
    - MDPZ7462 (cluster bores) where the salinity profiles indicate a zone of reduced salinity between ~63 and 70 mbgl, possibly associated with silcrete or top of the dolomite bedrock at this depth.
    - MDPZ7471 (cluster bores) where very minor decreases in salinity are evident from the salinity profiles at ~ 48 and ~55 mbgl, increasing again at 74 mbgl. These reduced salinities are coincident with permeable intervals of pisolite (46 to 55 mbgl) and calcrete (55 to 60 mbgl), with the increased salinity at the base of the bore corresponding with low permeability weathered shale below permeable BIF. It is inferred that the higher permeability units provide preferential pathways for the flow of fresher groundwater from the valley slope areas.
- Field readings taken from the discharge water during drilling generally correlates well with the salinity profile data although in many bores the discharge readings at depth are influenced by the inflow of groundwater from shallower depths (i.e. higher in the hole), this is particularly evident in the following cases:
    - At MDPZ7449 (cluster bores) the drilling discharge shows an increase in salinity from ~50 mbgl indicating down-hole leakage from the shallow high salinity zone when open-hole drilling (below the dual-rotary conductor casing) commenced.
    - The inflow of the fresher water at ~60 to 70 mbgl, at MDPZ7462 (cluster bores), influenced the drilling discharge from this depth to the end of the hole (drilled open-hole), resulting in a recorded salinity of 3,400 µS/cm rather than the ~13,000 to 14,000 µS/cm recorded in the salinity profile.
- The laboratory EC measurements for the initial water samples correlate fairly well with the initial salinity profile readings, particularly considering the collected sample is representative of the entire screened section (as it was collected either from the airlift of the completed bore or using a 12V pump during micro-testing).

The salinity profile data have also been imported into Leapfrog Geo to create a 3D model of the groundwater salinity across the Study Area. Figure 6.24 presents the model and associated cross-sections, whilst Figure 6.25 shows contoured groundwater salinity (EC) at the water table elevation. However, it should be noted that there are no bores and salinity profile data in the immediate claypan areas as access to and working in these conservation areas are restricted. Figure 6.24 and Figure 6.25 show a mound of saline water beneath the claypans, with fresher water to the north and south, particularly over the northern and southern alluvial fan areas. This suggests the saline water is originating from the claypans with increased salinities resulting from evaporation; this is explained further in subsequent sections of the report (Sections 6.7 and 10).

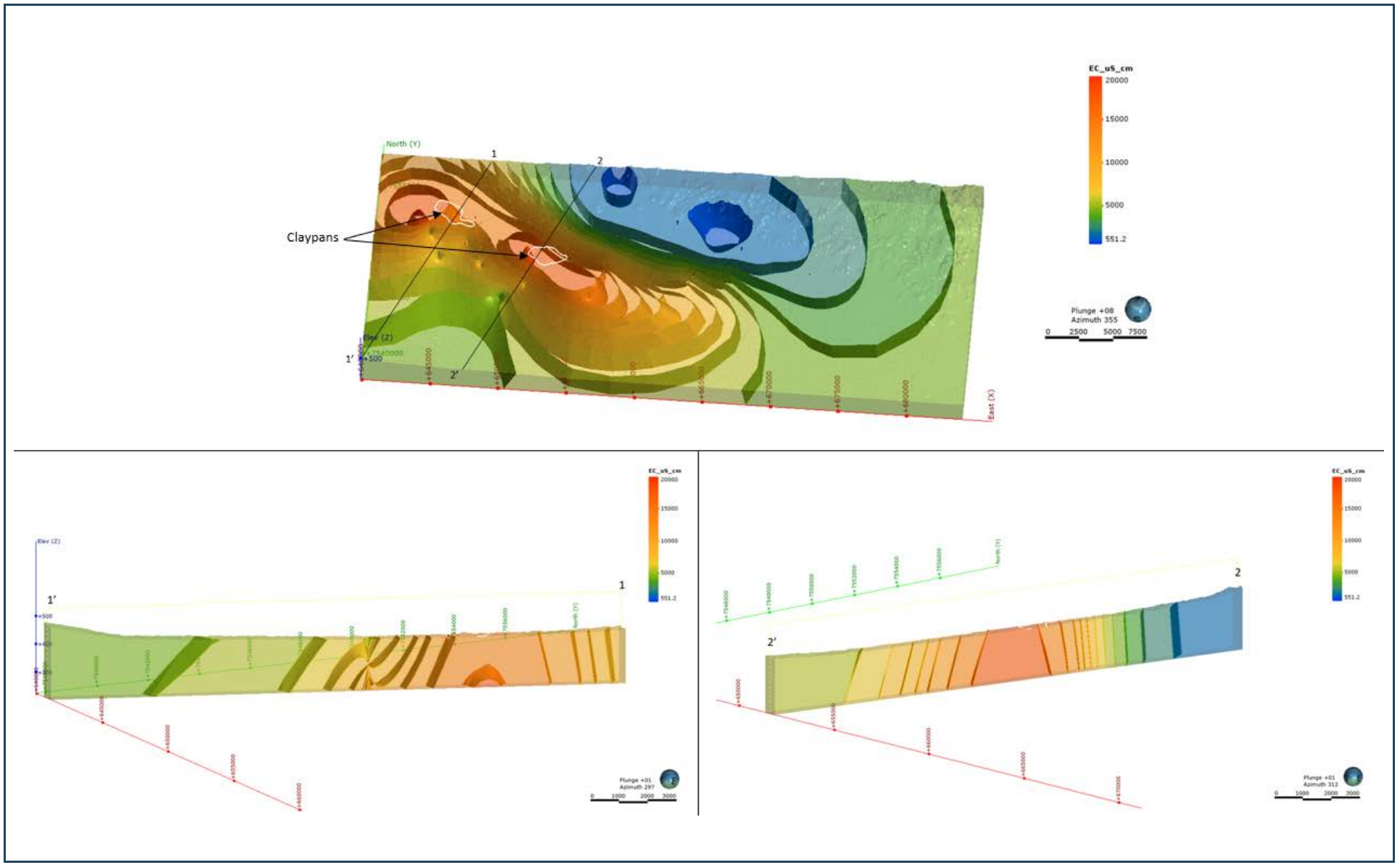


Figure 6.24 Groundwater Salinity Block Model

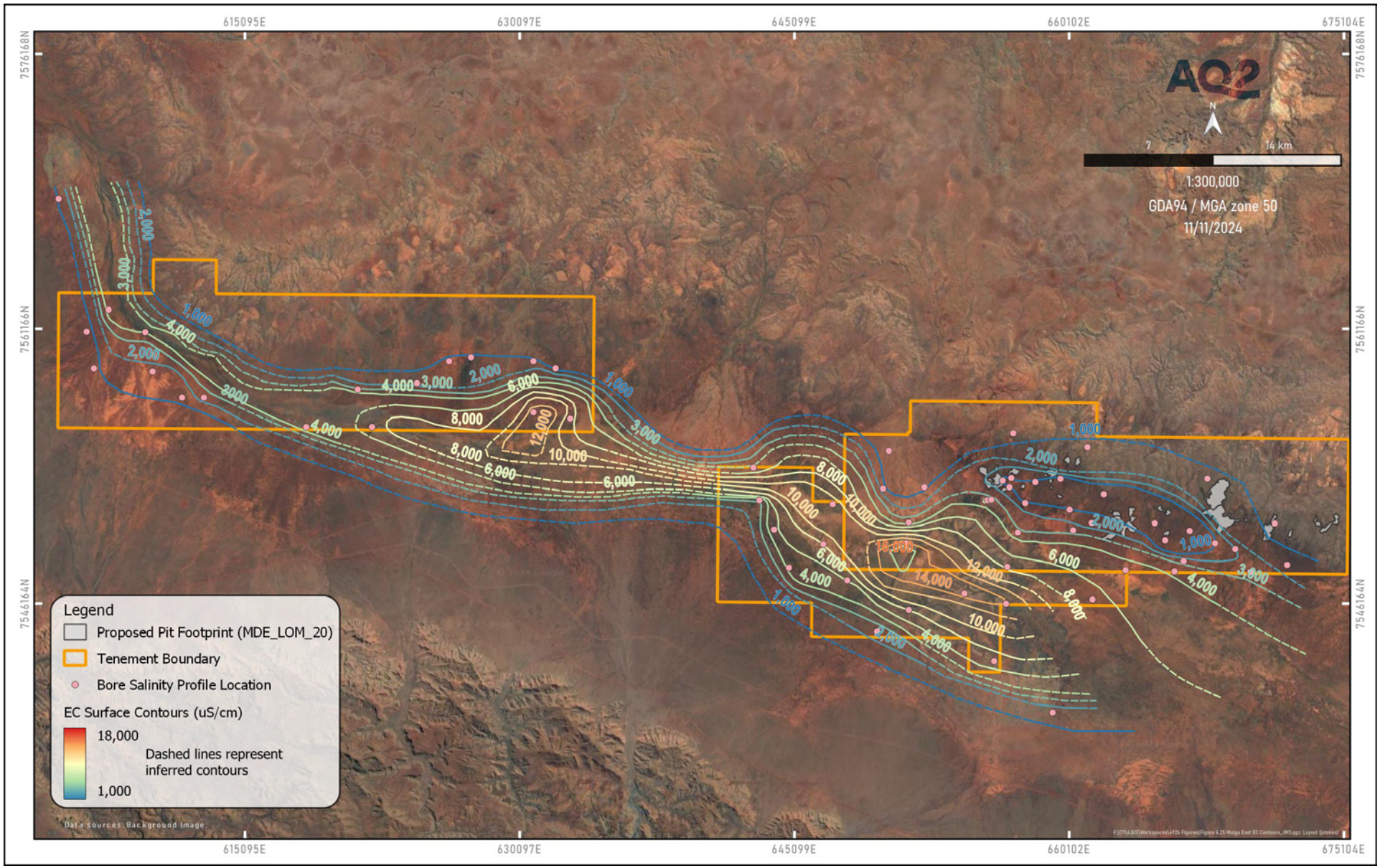


Figure 6.25 EC Contours at Water Table

6.7 Groundwater Salinity Changes

Due to the malfunctioning of the Solinst loggers, there are limited time series EC data between 2018/19 and December 2021 when new AquaTROLL loggers were installed in shallow monitoring bores near the claypans. Hydrographs of groundwater salinity (EC) are presented in Appendix K. The following salient points can be interpreted from the available EC data:

- Short-term spikes (i.e. increases) in groundwater EC at shallow monitoring bores, predominantly located on the valley floor, were evident in the early (Solinst logger) data. These are interpreted to show that salts are leached from the unsaturated zone into the groundwater system during the "first flush" (i.e. the initial surface water seepage leaches accumulated salts). This is most evident at MDPZ7457C (to the east of the Gnalka Gnoona Claypan) during the 2019/20 wet season (refer Figure 6.26). However, a similar response has not been observed in the 2021/22 and 2022/23 wet season; this is anticipated to be due to the smaller rainfall events, though may be related to the change in logger type / sensitivity.
- The reduced EC shown in some shallow salinity profiles, after the wet season (i.e. in May 2020), show that after the first flush of salts, fresher surface water recharges the groundwater system (i.e. on-going seepage of surface water does not continue to leach high volumes of salt as this was flushed during the early stages).
- The delayed increase in EC in deeper monitoring bores (equipped with LTC loggers in 2019/20), in response to the rainfall events, shows the diffusion and density-driven movement of salts from the surface to greater depths within the groundwater zone.

The reason for the increasing EC in response to the 2019/20 wet season at MDPZ456C, located away from the valley floor, is uncertain.

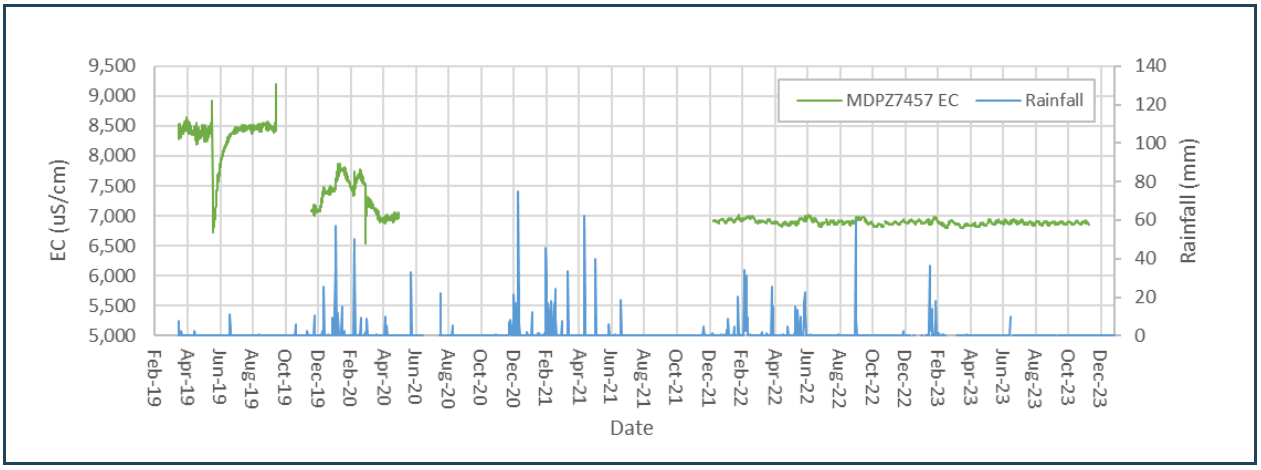


Figure 6.26 Groundwater Salinity Hydrograph for MDPZ7457C

7. ECOHYDROLOGICAL DATA SOURCES

7.1 Overview

AQ2 has undertaken the following four phases of ecohydrological assessment to date:

- Preliminary work in 2019 was focussed on the occurrence of potential groundwater dependent vegetation in the claypan areas.
- In 2021 the assessment of potential groundwater dependent vegetation was extended regionally with Mulga West becoming an additional focus area.
- In 2023 a more wholistic ecohydrological assessment was undertaken over the Mulga East and Malay Well tenement areas to assess the potential impact of a modified surface water regime (resulting from the proposed Project) on vegetation. The area of interest for this study was approximated by the flood modelling domain used for the associated surface water impact assessment.
- In 2024 the mapping of ecohydrological units (as defined in 2023) was extended to cover a wider area to support the recent flood modelling outlined in Section 4. Ground-truthing of the extended ecohydrological mapping area has not been undertaken.

The focus areas / areas of interest for the various ecohydrological assessments are presented in Figure 7.1.

7.2 Knowledge Review

In addition to the AQ2 groundwater and surface water assessments undertaken to date, a large body of environmental information relevant to the Study Area and adjacent areas has been documented in multiple studies. Key reports and data that were reviewed for the purposes of the ecohydrological assessment included the following:

- *Ecologia* 2021, Mulga East Baseline Terrestrial Vertebrate Fauna Assessment, Report prepared for Strategen-JBS&G (February 2021), *Ecologia* Environment, Perth
- Maia 2021a, *Mulga East Iron Ore Project, Mine Study Area Detailed Flora and Vegetation Assessment 2019-2020*, Report prepared for Strategen-JBS&G (March 2021), Maia Environmental Consultancy Pty Ltd, Perth
- Maia 2021b, *Mulga Downs West Flora and Vegetation Desktop Study*, Report prepared for Strategen-JBS&G (October 2021), Maia Environmental Consultancy Pty Ltd, Perth
- Maia 2022, *Mulga Downs Iron Ore Project, Mine and Borefield Study Area Detailed Flora and Vegetation Assessment 2019-2022*, Report prepared for Strategen-JBS&G (July 2022), Maia Environmental Consultancy Pty Ltd, Perth
- Mine Earth 2021, *Mulga East Iron Ore Project Baseline Soil and Landform Assessment*, Report prepared for Hancock Prospecting Pty Ltd (April 2021), Mine Earth Pty Ltd, Perth
- MWH 2015, *Ecohydrological Conceptualisation of the Fortescue Marsh Region*, Report Prepared for BHP Billiton Iron Ore (September 2015), MWH Australia, Perth
- Pinder A, Lyons M, Collins M, Lewis L, Quinlan K, Shiel R, Coppen R & Thompson F 2017, *Wetland diversity patterning along the middle to upper Fortescue valley (Pilbara: Western Australia) to inform conservation planning*, Department of Biodiversity, Conservation and Attractions, Perth.
- Woodgis 2021, *Mulga Downs Groundwater Dependent Vegetation Remote Sensing Assessment*, unpublished report prepared for AQ2 Pty Ltd, by Woodgis Environmental Assessment and Management, Perth.

- Environmental data sets:
  - Interpolated rainfall data are available from the Scientific Information for Land Owners project (SILO; Jeffrey et al. 2001). Available at:
  - Department of Primary Industry and Rural Development (DPIRD) (2019a). Soil Landscape Mapping - Rangelands (DPIRD-063) [shapefile]. Available at: https://catalogue.data.wa.gov.au/dataset/soil-landscape-mapping-rangelands.
  - DWER (2021). Clearing Regulations - Environmentally Sensitive Areas (DWER-046) [shapefile]. Available at: https://catalogue.data.wa.gov.au/dataset/clearing-regulations-environmentally-sensitive-areas-dwer-046.

For reference, background concepts relating to groundwater dependent vegetation are presented in Appendix L.

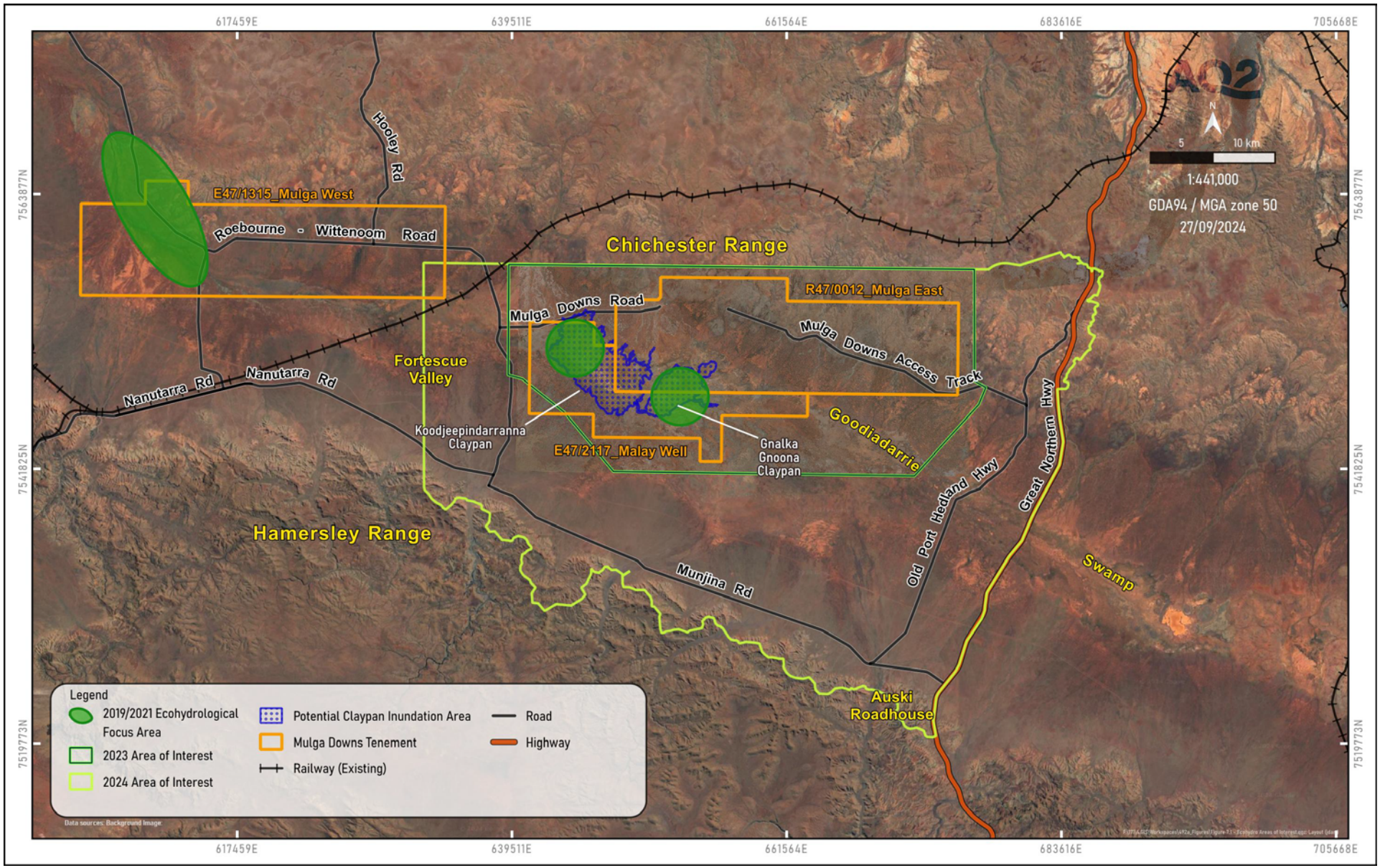


Figure 7.1 Ecohydrological Areas of Interest

7.3 Site Visits

Two site reconnaissance visits were completed by AQ2 personnel targeting the Mulga East / Malay Well tenements and Mulga West areas respectively:

- Mulga East/Malay Well: 11 -13 March 2019, and
- Mulga West: 19-22 October 2021.

During these reconnaissance visits, observations of the local area geomorphology and vegetation structure and composition were made and potential locations for ecophysiological measurements of vegetation were assessed.

Between 16 and 19 May 2023, AQ2 team members Mark Nicholls (Hydrologist) and Dan Huxtable (Ecologist) completed a site inspection of the 2023 area of interest (AOI). This involved an appraisal of the landscape from station tracks (by vehicle) and foot traverses of various landscape elements. Observations were made of the local area hydrological features, geomorphology as well as vegetation composition and structure. These are presented in Section 7.8.

The findings of the site inspection contributed to a landscape ecohydrological conceptualisation of the AOI, which is further described in Section 8.

7.4 2019/2021 Fieldwork Campaign – Ecophysiological Measurements

The overarching objective of the 2019/2021 fieldwork campaign was to determine the ecological water requirements of vegetation types in the Fortescue Valley with the potential to utilise groundwater. This involved consideration of multiple lines of evidence, including the collection of information for vegetation water balance model parameterisation as part of the sampling design.

AQ2 completed four field work campaigns involving the collection of ecophysiological data on the following dates:

- Wet season field program: 6-10 May 2019 (Mulga East and Malay Well tenements).
- Dry season field program: 22-27 October 2019 (Mulga East and Malay Well tenements).
- Dry season field program: 22 – 26 October 2021 (Mulga East, Malay Well and Mulga West tenements).
- Dry season field program: 20 – 25 October 2022 (Mulga East, Malay Well and Mulga West tenements).

Structural characteristics of overstorey tree species and plant water status (predawn and midday Ψ_{leaf}) were measured. Focus areas included *Eucalyptus victrix* woodlands at the Gnalka Gnoona claypan environs (Site A), the Koodjeepindarranna claypan environs (Site B) and the lower Fortescue River area in the western portion of the Mulga West tenement.

Details of the field work rationale and methodology, and subsequent data analysis methodologies, are described in the following sections.

7.4.1 Vegetation Structure Measurements

In 2019, vegetation structure was assessed in 21 randomly located quadrats sized 40 m by 60 m (2,400 m^2) in *E. victrix* dominated woodlands at each of the Gnalka Gnoona (Site A) and Koodjeepindarranna (Site B) claypans respectively. The locations of these quadrats are shown in Figure 7.2.

Within each quadrat:

- The total number of *E. victrix* trees was counted (by species).
- Diameter at breast height (DBH) was measured for all *E. victrix* trees > 10 cm.
- Understorey ground cover (percentage of land area) was visually estimated.
- Quadrat photographs were taken.

The DBH was used to calculate stand basal area (SBA; units m^2/ha) within the quadrat, being the sum of the cross sectional the area of all measured stems.

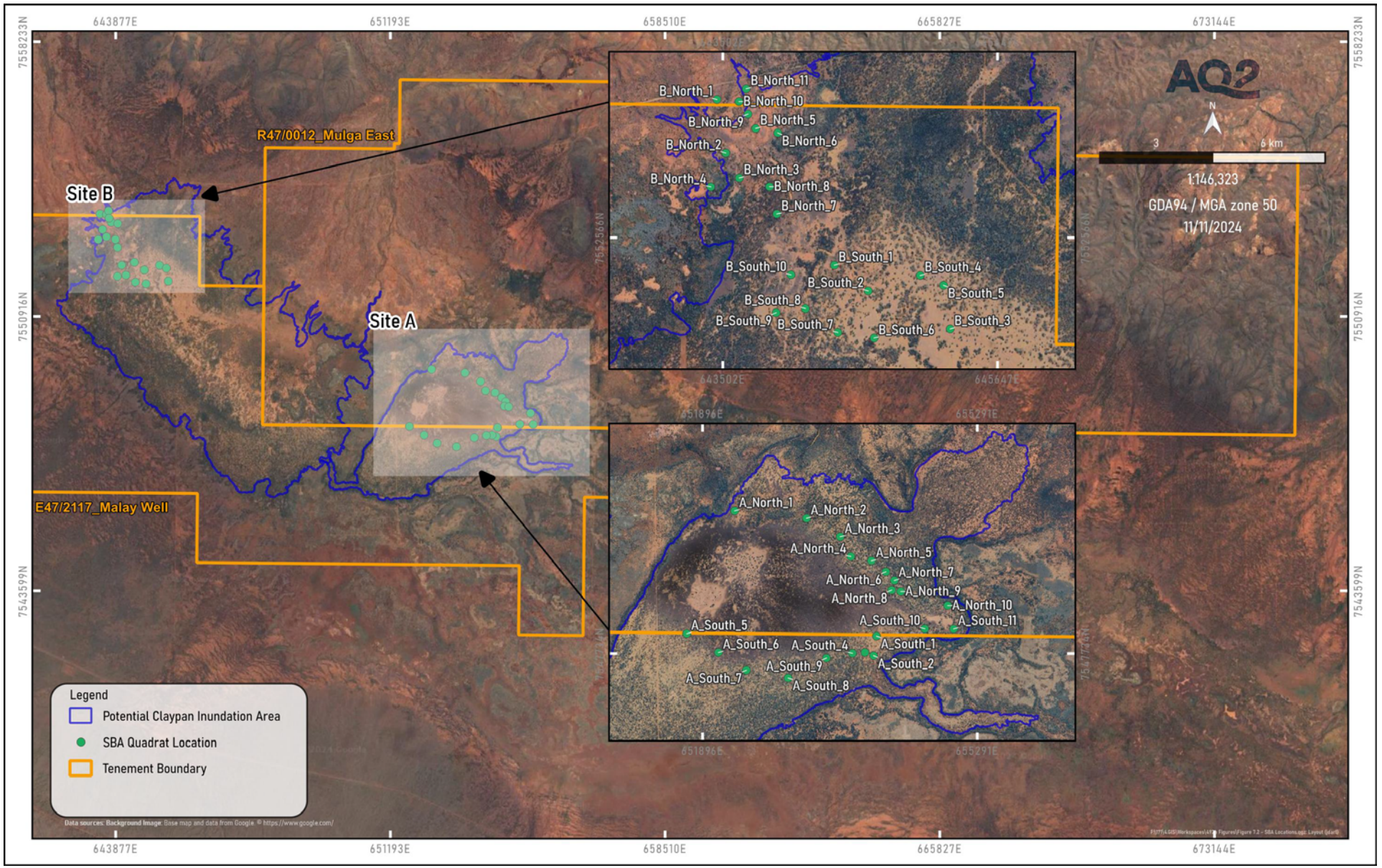


Figure 7.2 Sampling locations for ***Eucalyptus victrix*** woodland structure

For tree level comparison of stem growth, in the case of multi-stemmed trees the equivalent stem diameter was calculated as follows:

$$Dequiv. = 2 \times \sqrt{\sum_{k=1}^{n} \left(\frac{Dk}{2}\right)^2}$$

where:

D*equiv.* (cm) = equivalent stem diameter at 130 cm above ground level; and

D*k* (cm) = diameter of the *k*th stem at 130 cm above ground level.

7.4.2 Transpiration Flux Estimation

By application of the relationships presented in Figure 2, Appendix L (Basic Concepts), the following procedure was used to estimate the plausible range of annual water use by floodplain trees at each of the Fortescue Valley quadrat locations.

- Using tree stem measurement data from the quadrat, estimate plausible 'book ends' of daily transpiration rates (L/tree/year) using the 'upper bound' and 'lower bound' regression relationships between mean daily tree water use and DBH.
- Up-scale tree-level water use estimates to the stand level using the following procedure:
  - Annual water use per tree (L/year) calculated as tree daily water use (L/day) × 365.
  - Summation of annual water use per tree for all trees in the plot (m^3/year).
  - Conversion to unit area transpiration flux based on the measured plot areas (mm/year).

7.4.3 Leaf Water Potential Measurements

Multiple campaigns of predawn Ψ_{leaf} and midday Ψ_{leaf} measurements were completed in the Fortescue Valley *E. victrix* woodlands, summarised as follows:

Sampling location (refer to Figure 7.3)	6-10 May 2019	22-27 October 2019	22 – 26 October 2021	20 – 25 October 2022
Mulga East and Malay Well tenements Two locations referenced as north (N) and south (S) at the Gnalka Gnoona (Site A) and Koodjeepindarranna (Site B) claypans respectively	✓	✓	✓	✓
Two locations referenced as east (E) and west (W) at the Gnalka Gnoona (Site A) and Koodjeepindarranna (Site B) claypans respectively			✓	✓
Mulga West tenement Two locations referenced as north (N) and south (S) in and downstream of the Mulga West tenement (Site C).			✓	✓

At each of the locations in the Mulga East and Malay Well tenements, ten *E. victrix* trees were selected to cover the range in DBH that were present at each site (i.e. LWP was measured in trees that covered the range in tree sizes at each location).

At the Mulga West locations, Site CS included ten *E. victrix* trees spanning the range in DBH at the site; whilst Site CN included five trees each of the following overstorey species that were sampled given their prominence at this site: *E. victrix*, *Atalaya hemiglauca*, *Acacia ampliceps* and *Melaleuca glomerata*. The locations of all sampling sites are shown in Figure 7.3.

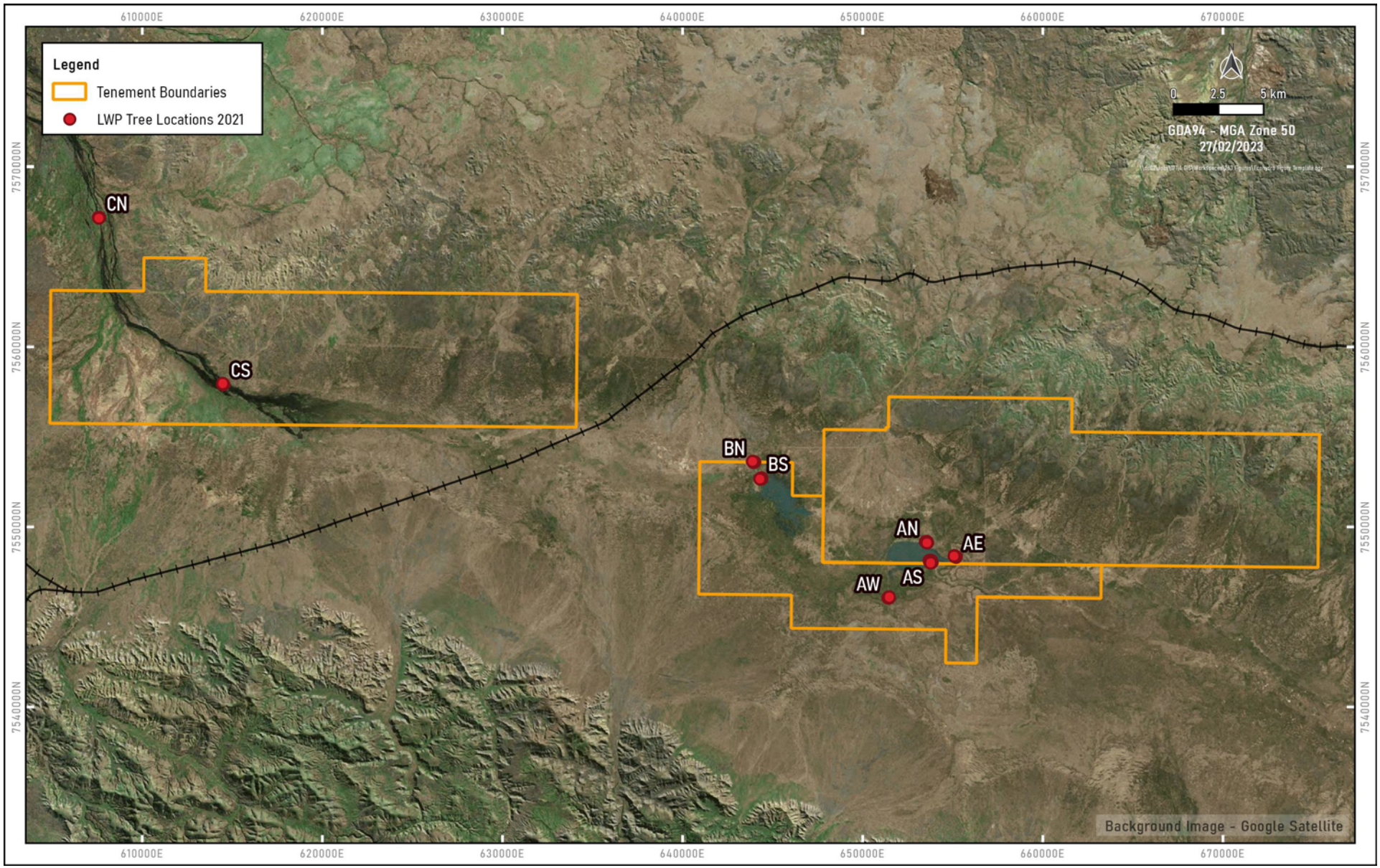


Figure 7.3 Sampling Locations for Leaf Water Potential Measurement

7.5 Land Systems

Land system mapping units developed by the Department of Agriculture and classified on the basis of landform, geology, geomorphology, soils and vegetation provide useful functional information about landscape elements (Van Vreeswyk et al. 2004). Land systems intersecting the 2024 AOI are shown in Figure 7.4. Key ecohydrological attributes of the major land systems are further described in Table 7.1.

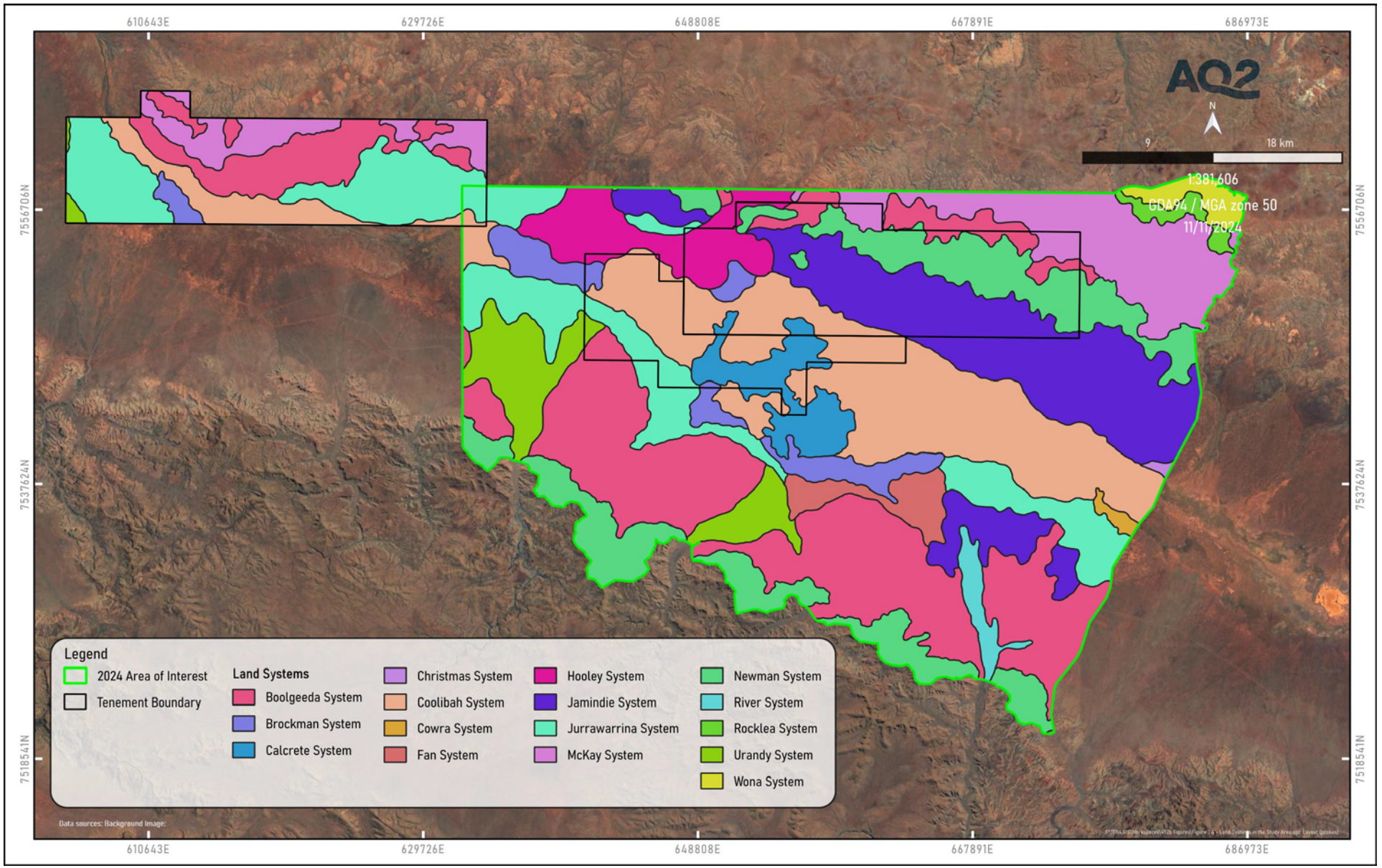


Figure 7.4 Land Systems in the Study Area and Surrounds

Table 7.1 Major Land Systems in the Study Area and Surrounds and their Ecohydrological Characteristics[2]

Land system and extent in Project area	Description	Geomorphology and soils	Key ecohydrology characteristics
Uplands of the Chichester Range			
Newman – comprises most of the Chichester Range uplands in the Mulga East area	Rugged jaspilite plateaux, ridges and mountains supporting hard spinifex grasslands. Widespread across the Pilbara region.	Erosional surfaces, characterised by skeletal soils (with abundant pebbles, cobbles and stones) and frequent rock outcropping. Soils are shallow and stony.	Provides catchment water supply to the Fortescue Valley wetlands. Dendritic drainage pattern (numerus small catchments). Xerophytic (drought tolerant) grass dominated vegetation predominantly rain fed.
McKay - comprises the Chichester Range uplands in the Mulga West area.	Hills, ridges, plateaux remnants and breakaways of meta sedimentary and sedimentary rocks supporting hard spinifex grasslands.	Erosional surfaces; hill tracts, ridges, plateaux remnants and breakaways with steep upper slopes and more gently inclined lower footslopes, restricted stony plains and interfluves. Soils are shallow and stony.	Provides catchment water supply to the Fortescue Valley wetlands. Moderately spaced tributary drainage patterns incised in narrow valleys in upper parts becoming broader and more widely spaced downstream. Xerophytic (drought tolerant) grass dominated vegetation predominantly rain fed.
Boolgeeda – flanking areas of the Newman uplands	Stony lower slopes and plains below hill systems, supporting hard and soft Spinifex grasslands and less frequently Mulga shrublands. Widespread across the Pilbara region	Quaternary colluvium parent materials. Closely spaced dendritic and sub-parallel drainage lines. Predominantly depositional surfaces characterised by red loamy soils of shallow to moderate depth.	Minimal contribution to the catchments of the Fortescue Valley wetlands. Xerophytic (drought tolerant) vegetation. Living plant cover typically less than 60%; with denser bands associated with drainage lines. Typically <50 mature trees and tall shrubs per hectare.
Wona – comprises a small area in the Chichester Range uplands in the northeast of the 2024 AOI	Extends to the northeast within the Chichester Range.	Level to very gently inclined basaltic plains. Soils mostly comprise self-mulching cracking clays and some deep red-brown non-cracking clay with stony mantles.	Minimal contribution to the catchments of the Fortescue Valley wetlands, mainly local infiltration. Tussock grassland communities predominantly rain fed.

[2] Adapted from Van Vreeswyk et al. (2004).

Land system and extent in Project area	Description	Geomorphology and soils	Key ecohydrology characteristics
Alluvial plains			
Jamindie - comprises the majority of the alluvial plain at the base of the Chichester Range in the Mulga East tenement	Stony hardpan plains and rises supporting groved Mulga shrublands, occasionally with spinifex understorey.	Depositional surfaces including non-saline plains with hardpan at shallow depth, stony upper plains and low rises on hardpan or rock. Minor stony gilgai plains, sandy banks and low rises and hills. Shallow loamy soils (often stony/gravelly) are predominant.	Widely spaced tributary drainage tracts and channels, dissecting and separated by relictual alluvial fans. These support extensive banded vegetation formations sustained by localised surface water distribution (sheet flow). This catchment format controls the delivery of flows to the Fortescue Valley, contributing to heterogeneity in the wetland complex.
Hooley – comprises the alluvial plain in the far west of the Mulga east tenement.	Alluvial clay plains supporting a mosaic of snakewood shrublands and tussock grasslands.	Depositional surfaces including level plains of clayey and stony alluvium as a mosaic of surfaces with gilgai microrelief. Soils are mainly deep red/brown non-cracking clays and self-mulching cracking clays.	Mostly sluggish internal drainage, however several drainage tracts with well-defined channels convey flows into Brockman Land system and Fortescue Valley wetlands downstream. Vegetation is sustained by deep soils with relatively large vadose storage.
Brockman – occurs in a zone between the Hooley and Coolibah land systems in the Mulga East tenement; and between the Jurrawarrina and Coolibah land systems in the Mulga West tenement.	Alluvial plains with cracking clay soils supporting tussock grasslands. Note: In the Hamersley Range, this land system may support a rare tussock grassland dominated by *Astrebla lappacea* constituting a Priority Ecological Community (P1) (DBCA 2022).	Depositional surfaces derived from Quaternary alluvium. Non-saline alluvial plains with clay soils and gilgai micro-relief, flanked by slightly more elevated hardpan washplains. Soils are mainly self-mulching cracking clays and red/brown non-cracking clays, with some red loamy earths on elevated washplains.	Appears to occur at the break of slope in an area of fine textured, outwashed sediment accumulation. Sluggish internal drainage with occasional channel; however in the Mulga East tenement this unit is also crossed by a major channel feeding into the Fortescue Valley wetlands. Vegetation is sustained by deep soils with relatively large vadose storage.
Jurrawarrina - comprises the southern alluvial plain bordering the Fortescue Valley wetlands in Malay Well tenement. The major unit bordering the Fortescue Valley wetlands in the Mulga West tenement.	Hardpan plains and alluvial tracts supporting Mulga shrublands and tussock and spinifex grasslands.	Depositional surfaces derived from Quaternary alluvium and colluvium. Plains receiving overland sheetflow characterised by banded Mulga vegetation; and broad drainage tracts with or without defined channels. Soils are a mixture of red/brown clays, loams, earths and duplex types.	Functionally similar to the Jamindie land system, but with less well-defined drainages and more patchy banded vegetation formations.

Land system and extent in Project area	Description	Geomorphology and soils	Key ecohydrology characteristics
Fortescue River valley/drainage tract			
Calcrete – prominent in the Malay Well tenement and contributes to the Fortescue Valley wetlands area.	Low calcrete platforms and plains supporting shrubby hard spinifex grasslands.	Tertiary calcrete formed in valley fill deposits, with minor Quaternary alluvium. Drainage is generally indistinct. Soils are mainly shallow calcareous loams (<50 cm overlying calcrete), with minor calcareous loamy earths and red shallow loams.	The vegetation mosaic is inter-dispersed by calcrete outcrops and small depressions. Includes some incised channel zones connecting claypans. Vegetation water requirements include localised surface water distribution (e.g. shedding from outcrops). Major floods are likely to replenish deep soil water stores infrequently. Periods of prolonged waterlogging may occur. Subsoil calcrete sheeting is likely to constitute a barrier to tree root penetration.
Coolibah – encompasses the majority of the Fortescue Valley wetlands area in the Mulga East, Malay Well and Mulga West tenements.	Coolibah – Flood plains with weakly gilgaied clay soils supporting Coolibah woodlands with tussock grass understorey.	Depositional surfaces including active flood plains with shallow, meandering and anastomosing drainages and extensive, largely bare claypans. The soil is typified by deep red/brown cracking and non-cracking clays.	Encompasses the Gnalka Gnoona and Koodjeepindarranna Claypans. Fringing woodlands include *Eucalyptus victrix* and *Acacia distans;* also *Acacia stenophylla* is a notable species in eastern areas. Soil water replenishment by surface water inflows is important for sustaining the woodland trees and grasses. Major floods are likely to replenish deep soil water stores infrequently. Includes areas subject to periods of prolonged waterlogging. Contains Environmentally Sensitive Area (ESAs), including the Freshwater Claypans of the Fortescue Valley PEC (DBCA 2022).

7.6 Soil and Landform Assessment

A soil and landform assessment of the AOI and surrounds was completed by Mine Earth (2021). This work involved sampling and observations at 24 locations (refer Figure 7.5); including backhoe pits in areas where deep soil profiles were present (13 sites) or hand digging in areas where only shallow / skeletal soils were present and/or where access was restricted (11 sites).

Observations made at each soil sampling location during the Mine Earth (2021) fieldwork campaign included a description of soil surface characteristics, soil profile morphology, vegetation assemblages and surface drainage characteristics. Samples for physicochemical analysis were taken from two to four depth intervals at each soil sampling location, depending on the near-surface soil profile morphology and depth of excavation possible. The following parameters were measured:

- Physical characteristics:
  - Soil texture and particle size distribution;
  - Soil structural stability (Emerson Dispersion Test);
  - Saturated hydraulic conductivity (Ksat); and
  - Water retention characteristics (field capacity).
- Chemical characteristics:
  - Soil pH;
  - Electrical conductivity;
  - Organic carbon;
  - Exchangeable cations;
  - Plant available nutrients (N, P, K and S); and
  - Total metal concentrations.

Complementing the Mine Earth (2021) data set:

- Soil surface characteristics were appraised at multiple points by AQ2 during the May 2023 site inspection and topsoil (0-10 cm) was opportunistically sampled at eight locations. These samples were submitted to the CSBP Soil and Plant laboratory for selected physicochemical testing to complement the Mine Earth (2021) results (refer to Appendix M). Sampling locations are shown in Figure 7.5 and results are discussed in Section 7.8.2.
- Five alluvium 'grab' samples were collected by AQ2 in 2019 from locations proximal to the Gnalka Gnoona and Koodjeepindarranna claypans (Figure 7.5). These samples were obtained from drilling sump pits at approximate depths of 0.5 mbgl. The samples were submitted to geotechnical laboratory for determination of particle size distribution (PSD) (refer to Appendix M). Results are presented in Section 9.3.

Note that to date no soil sampling has been conducted in the Mulga West area.

From the results of their investigation, Mine Earth (2021) identified five soil-landform associations described as follows:

- Low hills and rises (of the Chichester Range):
  - Low undulating hills, minor outcropping rock in some areas.
  - Shallow / skeletal soils over fractured / weathered and competent rock.
  - High percentage of competent rock fragments through the surface soil profile.
  - Hills dissected by narrow, shallow drainage channels.
  - Soil pH moderately acidic-neutral.

- Alluvial plains (associated with alluvial fans):
  - Relatively flat, with gentle relief towards valley floor. Dissected by multiple minor drainage channels.
  - Relatively deep, earthy soil profiles with well-structured soils close to surface and massive soil horizons below.
  - Moderate percentage of competent rock fragments through the surface soil profile.
  - Soil pH neutral.
- Calcareous flats (of the Fortescue Valley):
  - Relatively flat and slightly elevated above surrounding landscape. Some outcropping calcrete present.
  - High percentage of competent rock fragments through the surface soil profile, typically increasing with depth.
  - Where the calcrete does not outcrop, weathered calcrete is commonly encountered at depths of 50 to 100 cm.
  - Soil pH moderately alkaline near the surface, becoming strongly alkaline at depth.
- Floodplains (of the Fortescue Valley):
  - Valley floor with depositional areas and evidence of surface sheet-flow.
  - Moderate, poorly defined drainage channels.
  - Relatively deep, earthy soil profiles with well-structured soils close to surface and massive soil horizons below.
  - Relatively low coarse fraction through soil profiles.
  - Soil pH neutral near the surface, becoming strongly alkaline at depth.
- 'Claypans':
  - Flat depositional areas associated with break of slope areas in the northern Fortescue Valley, near the base of alluvial fans.
  - Generally homogenous, weakly structured to massive soil profiles with high clay content.
  - Low percentage of competent rock material.
  - Soil pH neutral near the surface, becoming strongly alkaline at depth.

Note that Mine Earth (2021) did not complete any soil sampling in the Gnalka Gnoona and Koodjeepindarranna Claypans.

Soil electrical conductivity (EC), nitrate-N and plant available sulfur-S levels reported by Mine Earth (2021) are shown in Figure 7.6. The soils of the uplands and alluvial plains were non-saline. In the case of soil types in the Fortescue Valley, soil salinity was variable with respect to soil-landform associations and depth within the soil profile. The most saline soils documented by Mine Earth (2021) occurred in a non-vegetated stony plain depression (ME16 and ME18; saturated paste EC 4.5 to 9.1 dS/m); located north of the Gnalka Gnoona Claypan near the base of an alluvial fan originating from the Chichester Range. These results are indicative of:

- A break of slope landscape position, where channelised drainage dissipates and run-off accumulates.
- Low permeability clay at relatively shallow depth, contributing to water ponding and evaporative concentration of salts.

In other parts of the Fortescue Valley floodplains, where the surface soil layers were better structured and more permeable, salts were observed to accumulate in deeper subsoil layers (circa 50 cm depth; Figure 7.6.). This is inferred to be a consequence of:

- Higher infiltration rates and percolation through near surface layers.
- Lower permeability subsoils, which constrain deeper flushing of salts.
- Vegetation root system morphology, with root water uptake concentrated near the lower permeability subsoil interface.

The decrease in EC and nitrate at 100 cm depth at all sampling locations indicates a lack of flushing of salts below the root zone at the time of measurement. These data suggest that the vast majority of surface water inputs are captured in the upper soil profile and used by vegetation (i.e. a store and release dynamic). Percolation and salt flushing into the deeper profile probably only occurs in association with very large and infrequent rainfall events.

From the surficial sampling sites (0-10 cm layer) undertaken by Pinder et al. (2017) at the Gnalka Gnoona and Koodjeepindarranna Claypans, they reported higher clay contents (refer below) compared to the Mine Earth (2021) samples outside of the claypan areas.

- Gnalka Gnoona:
  - Site FV14A: Clay = 34.5%; Silt = 15.5%; Sand = 50.0%
  - Site FV19A: Clay = 40.5%; Silt = 13.5%; Sand = 46.0%
- Koodjeepindarranna:
  - Site FV17A: Clay = 34.4%; Silt = 18.8%; Sand = 46.8%
  - Site FV18A: Clay = 39.0%; Silt = 22.5%; Sand = 38.5%

The high clay content near the surface of the claypans contributes to restricted infiltration and protracted ponding following large rainfall events (i.e. analogous to the aforementioned stony plain depressions at break of slope locations along the northern margin of the Fortescue Valley).

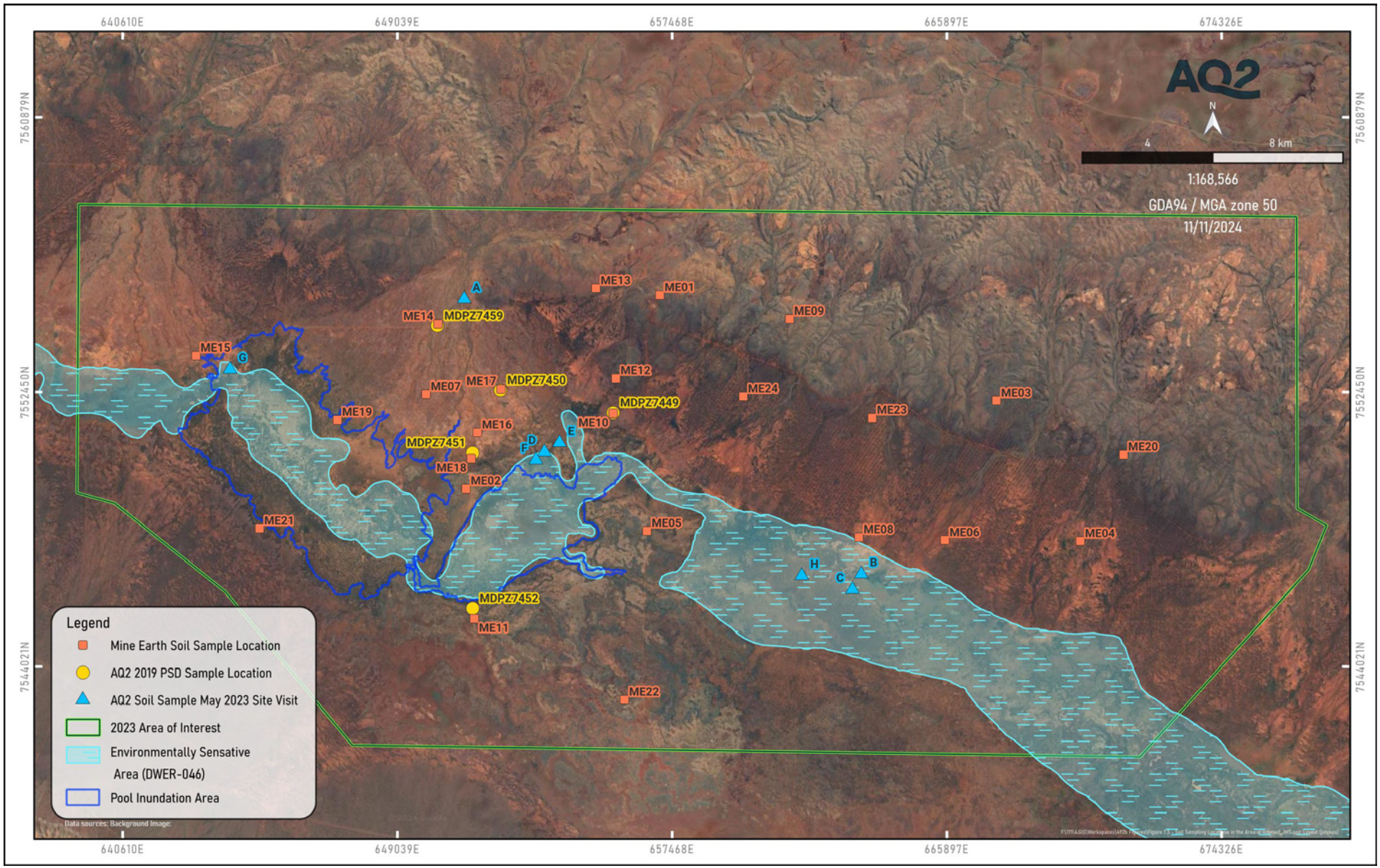


Figure 7.5 Soil Sampling Locations in the Area of Interest

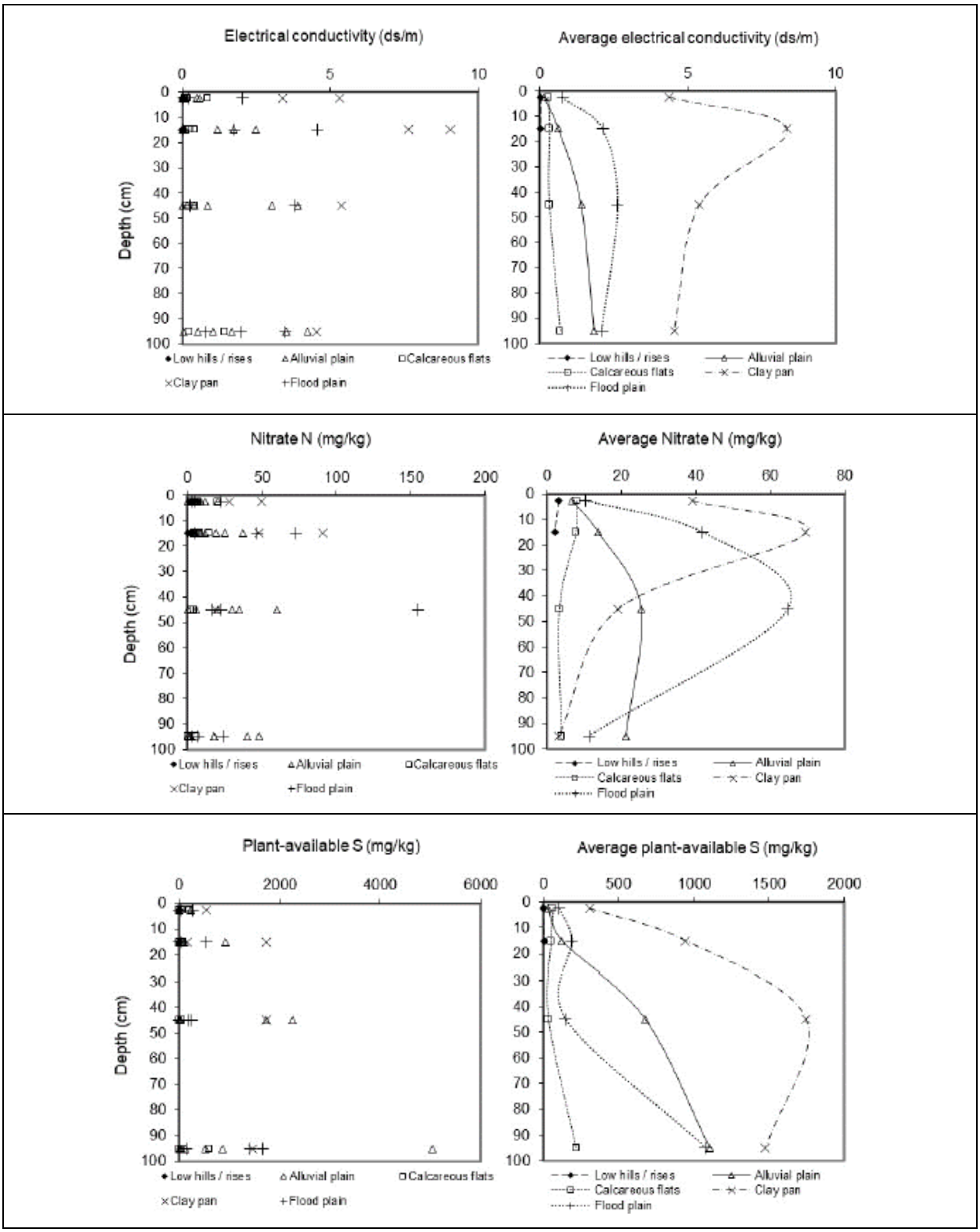


Figure 7.6 Soil Salinity and Nitrate Observations in the Area of Interest - reproduced from Mine Earth (2021)

Top: Individual and average electrical conductivity (saturated paste EC; dS/m) of soils with depth for each soil-landform association.

Centre: Individual and average Nitrate-N concentration (mg/kg) of soils with depth for each soil-landform association.

Bottom: Individual and average plant available Sulfur-S concentration (mg/kg) of soils with depth for each soil-landform association.

7.7 Vegetation Mapping

A comprehensive assessment of vegetation in the Study Area and surrounds, including desktop reviews and multiple on-ground surveys in the period 2012 to 2022, has been completed by Maia Environmental Consultancy Pty Ltd (Maia, 2022). The following sections summarise salient findings from this work.

7.7.1 Vegetation Types

As shown in Figure 7.7, 23 vegetation types, including one mosaic vegetation type, have been mapped over the Study Area and surrounds (Maia, 2022); including the Mulga West area. Those within the Study Area are summarised in Table 7.2 and their key ecohydrological characteristics are described in Table 7.3.

Maia (2022) considered twelve of these vegetation types (including the mosaic) to be locally significant for a number of reasons as described in Table 7.3; these types included ASL (2), AWL (1), AWL (2), AWL (3), AdEvWL, MSL (1), MSL (2), EfEbTG, BpoFL, MTG (2) and TvHG plus the mosaic of AdEvWL and BpoFL.

The keystone species *Eucalyptus victrix* occurs in 10 vegetation types: AdEvWL, ASL (2), AWL (2), BpoFl, EfEbTG, EvWL, MSL (1), MSL (2), MTG (1) and MTG (2). Salient aspects are as follows:

- *E. victrix* occurs in low, open woodland to woodland formations in vegetation types AdEvWL and EvWL on the Fortescue Valley flats. In all other vegetation types, in upgradient locations, *E. victrix* occurs as scattered or isolated trees. These trees constitute outliers from the core valley woodlands, with recruitment presumably facilitated by a combination of specific hydrological regimes (e.g. major floods providing seed dispersal) and micro niche habitat characteristics (e.g. pockets of deeper soil with soil moisture retention).
- The *Acacia* woodland/shrubland vegetation types (i.e. ASL (2) and AWL (2)), sparse to open shrubland types (i.e. MSL (1), and MSL (2)) and tussock grass dominated types (i.e. MTG (1) and MTG (2)) are all upgradient of the *E. victrix* woodland units, on the alluvial fans or calcrete rises in the Fortescue Valley.
- Vegetation type BpoFl is downgradient of the *E. victrix* woodland units, with the subtlety of the topography giving rise to mosaic patterning. It is associated with largely bare claypans/depressions. The dominant species *Bergia perennis* subsp. *obtusifolia* (herb), *Duma florulenta* (shrub), *Eriachne benthamii* (grass) and *Sporobolus mitchellii* (grass) all have a high tolerance of flooding/waterlogging, drought and salinity; reflecting the adverse growing conditions in these areas. Where present, *E. victrix* trees occur on slightly raised areas within these claypans. A notable subordinate species is the samphire *Tecticornia verrucosa*, which is an indicator of fresh water or slightly saline claypans and lakes (Wilson 1972), Unlike many other samphire species, it is a short-lived perennial that typically persists for 2-3 years (Pinder et al. 2017).
- Vegetation type EfEbTG is associated with local depressions in slightly elevated parts of the Fortescue Valley, flanking the valley thalweg that support relatively dense tussock grass communities *of Eriachne flaccida* and *E. benthamii*. Both of these grass species are adapted to periodic phases of flooding/waterlogging.

Two claypan areas in the AOI are listed as the P1 PEC 'Freshwater claypans of the Fortescue Valley'. Vegetation types EfEbTG, AdEvWL, BpoFl, the mosaic of AdEvWL / BpoFL, MSL(1), MSL(2) and MTG (3) are mapped within the buffered extent of these PEC units (Maia, 2022).

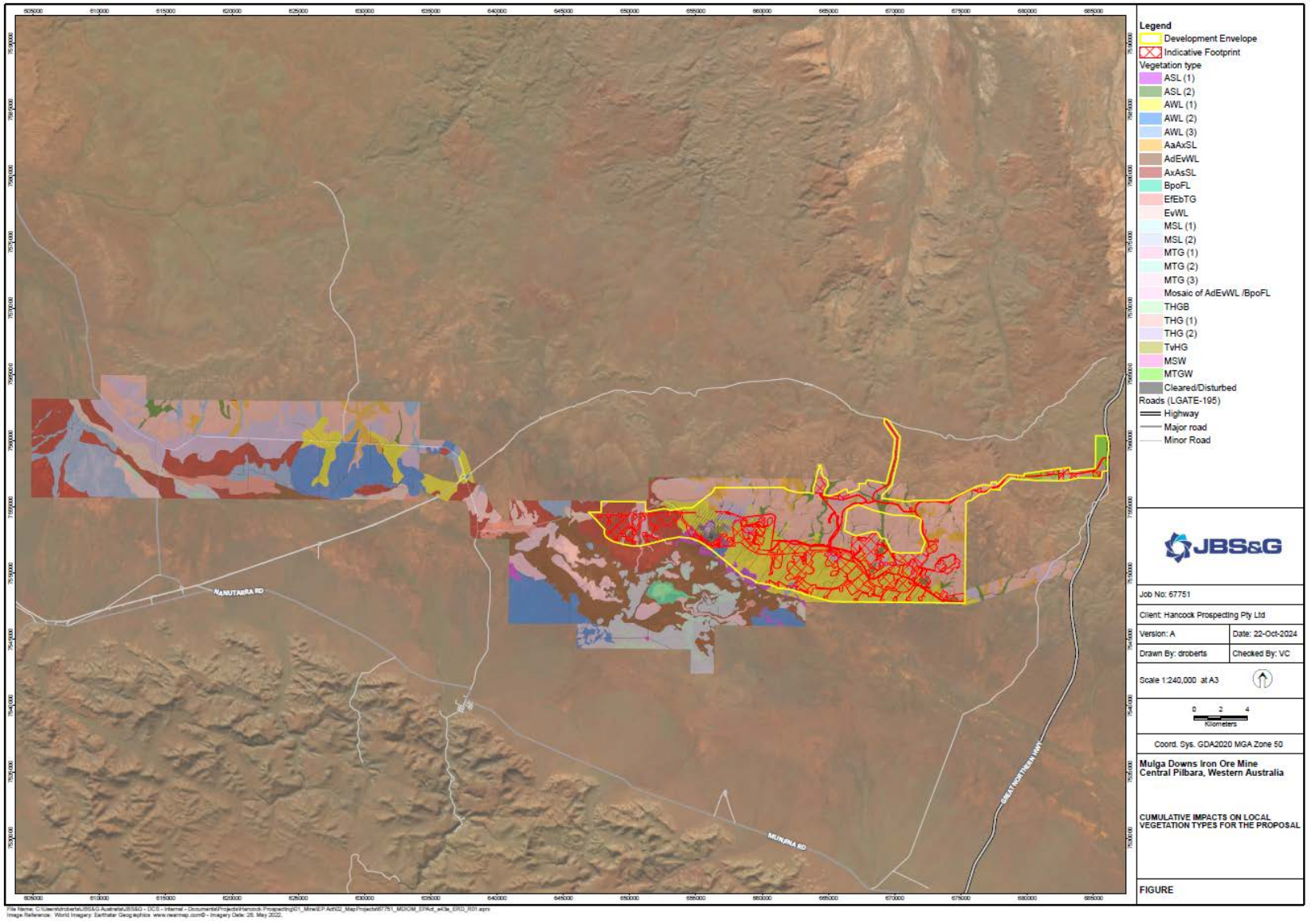


Figure 7.7 Vegetation Mapping Units in the Area of Interest and Surrounds (from JBS&G 2024b)

Table 7.2 Mapped Vegetation Types in the Area of Interest

Vegetation Type	Description
AaAxSL: Acacia Tall Sparse Shrubland	Tall Sparse Shrubland of *Acacia aneura* (alliance) and *A. xiphophylla* with a Low Sparse Shrubland of *Eremophila cuneifolia* and a Sparse Hummock Grassland of *Triodia epactia* and/or *T.basedowii.*
AdEvWL: Acacia and Eucalyptus Low Open Woodland	Low Open Woodland to Low Woodland of *Acacia distans* and *Eucalyptus victrix* sometimes with a Tall Sparse Shrubland of *Acacia stenophylla* or *A. tetragonophylla* and a Shrubland to a Sparse Shrubland of *Duma florulenta*.
ASL (1): Acacia Tall Sparse to Open Shrubland	Tall Sparse to Open mixed Shrubland mainly of *Acacia synchronicia*, *A. tetragonophylla*, *A.xiphophylla* with a mixed Sparse Chenopod Shrubland mainly of *Sclerolaena densiflora*, *S. cuneata* and *S. costata* and Isolated mixed Tussock Grasses mainly of *Sporobolus australasicus*, *Enneapogon polyphyllus* and *Dactyloctenium radulans.*
ASL (2): Acacia Tall Shrubland	Mixed Tall Acacia Shrubland mainly of *Acacia tumida* var. *pilbarensis*, *A. pyrifolia* and *A. maitlandii* with a Sparse Tussock Grassland of *Themeda triandra* and Low Isolated Trees of *Corymbia hamersleyana* and / or *Eucalyptus victrix*.
AWL (1): Acacia Low Woodland or Tall Shrubland	Low Woodland / Tall Shrubland to Low Isolated Trees / Shrubs of *Acacia aneura* (complex) with a mixed Low Sparse Shrubland mainly of *Dodonaea petiolaris*, *Eremophila forrestii* and *Abutilon otocarpum* and Isolated Low Trees of *A. pruinocarpa*.
AWL (2): Acacia Low Woodland or Tall Shrubland	Low Woodland / Tall Shrubland to Low Isolated Trees / Tall Shrubs of *Acacia aneura* (complex,) *A. synchronicia* and *A. tetragonophylla* with a mixed Low Sparse Shrubland mainly of *Solanum lasiophyllum*, *Abutilon otocarpum* and *Sida platycalyx* and a Sparse Tussock Grassland to Isolated Tussock Grasses mainly of *Sporobolus australasicus*, *Enneapogon cylindricus* and *Aristida contorta*.
AWL (3): Acacia Low Woodland	Low Woodland of *Acacia aneura* (complex) mainly *Acacia aptaneura*, *A. aneura* and *A. incurvaneura* with a mixed Tall Shrubland mainly of *A. synchronicia*, *A. tetragonophylla* and *Hakea lorea* subsp. *lorea* with a Sparse Tussock Grassland to Isolated Tussock Grasses mainly of *Sporobolus australasicus*, *Enneapogon cylindricus* and *Aristida contorta*.
AxAsSL: Acacia Tall Shrubland	Tall Sparse Shrubland of *Acacia xiphophylla* and / or *A. synchronicia* with a mixed Sparse Chenopod Shrubland mainly of *Sclerolaena cuneata*, *S. bicornis*, *S. cornishiana* and a Sparse Tussock Grassland of *Eragrostis xerophila*.
BpoFL: Bergia Forbland	Claypans mostly bare of vegetation but with scattered *Bergia perennis* subsp. *obtusifolia* and mixed tussock grasses mainly of *Eriachne benthamii* and *Sporobolus mitchellii.*
EfEbTG: Eriachne Tussock Grassland	Tussock Grassland of *Eriachne flaccida* and *E. benthamii* with Isolated Trees of *Eucalyptus victrix*.
EvWL: Eucalyptus Low Open Woodland	Low Open Woodland of *Eucalyptus victrix* and +/- *Acacia distans* with a Tussock Grassland of *Eulalia aurea*, *Eriachne benthamii* and *E. flaccida* and an Open Shrubland of *Melaleuca glomerata*.
Mosaic of ***AdEv***WL / ***Bpo***FL.	Refer to *AdEvWL* and *BpoFL* descriptions.

Vegetation Type	Description
MSL (1): Mixed Mid Shrubland	Sparse to Open mixed Shrubland mainly of *Melaleuca glomerata*, *Acacia synchronicia* and *A. tetragonophylla* and with a mixed Tussock grassland mainly of *Eragrostis pergracilis*, *Eriachne benthamii* and **Cenchrus setiger* or occasionally with a Hummock Grassland of *Triodia epactia* and Low Isolated Trees of *Eucalyptus victrix*.
MSL (2): Mixed Tall Shrubland	Sparse to Open mixed Tall Shrubland mainly of *Acacia synchronicia*, *A. tetragonophylla*, and *Melaleuca glomerata* over a mixed Low Shrubland mainly of *Indigofera monophylla*, *Solanum lasiophyllum* and *Stemodia grossa* and either a Sparse Tussock grassland of *Eragrostis desertorum* or a Hummock Grassland of *Triodia epactia*.
MTG (1): Mixed Tussock Grassland	Mixed Tussock Grassland mainly of *Eragrostis xerophila*, *Eulalia aurea* and **Cenchrus setiger* with a mixed Tall Sparse Shrubland mainly of *Acacia coriacea* subsp. *pendens*, *A. tetragonophylla* and *A. synchronicia* with a Low mixed Sparse Shrubland mainly of *Pluchea rubelliflora*, *Pterocaulon sphacelatum* and *Salsola australis*.
MTG (2): Mixed Tussock Grassland	Sparse to Open mixed Tussock Grassland mainly of *Eriachne benthamii*, *Aristida latifolia* and **Cenchrus setiger* with a Sparse mixed Shrubland mainly of *Acacia synchronicia*, *A. tetragonophylla*, *A. distans* with Low Isolated Trees of *Eucalyptus victrix*.
MTG (3): Mixed Tussock Grassland	Sparse to Open mixed Tussock Grassland mainly of *Eragrostis xerophylla*, *Eriachne benthamii*, and *Astrebla lappacea* with a mixed Forbland, mainly of *Stemodia kingii*, *Operculina aequisepala* and *Cullen cinereum* with Isolated shrubs of *Acacia synchronicia* or *Vachellia farnesiana*.
THGB: Triodia Hummock Grassland on Basaltic Terrain	Includes Triodia *epactia* and *T. brizoides* hummock grassland with sparse *Acacia inaequilatera* and *Grevillea pyramidalis subsp. leucadendron*
THG (1): Triodia Hummock Grassland	Mixed Hummock Grassland mainly of *Triodia basedowii*, *Triodia brizoides* and *T. vanleeuwenii* with a Tall Sparse Shrubland of mixed Acacia species mainly *Acacia atkinsiana*, *A. maitlandii*, *A. ancistrocarpa* with Low Isolated Trees of *Eucalyptus leucophloia* subsp. *leucophloia* +/- *Corymbia hamersleyana*.
THG (2): Triodia Hummock Grassland	Mixed Hummock Grassland mainly of *Triodia basedowii*, *T. epactia* and *T. vanleeuwenii* with a Sparse mixed Shrubland mainly of *Acacia aneura*, *A. aptaneura* and *A. atkinsiana* and Isolated Low Trees of *A. pruinocarpa* and / or *Eucalyptus leucophloia* subsp. *leucophloia*.
TvHG: Triodia Hummock Grassland	Hummock Grassland of *Triodia veniciae* with Isolated Shrubs of *Acacia marramamba* and *A. atkinsiana*.
Cleared	

Table 7.3 Ecohydrological Characteristics of Vegetation Types in the Area of Interest

Vegetation Type	Key Ecohydrological Characteristics
AaAxSL: Acacia Tall Sparse Shrubland	Occurs in upland areas of the Chichester Range. Vegetation water sources comprise direct rainfall. Dominant species include members of the *Acacia aneura* (complex) and *A. xiphophylla,* with Low Sparse Shrubland of *Eremophila cuneifolia* and a Sparse Hummock Grassland of *Triodia epactia* and/or *T. basedowii*. These are generally regarded as shallow rooted, drought tolerant species.
AdEvWL: Acacia and Eucalyptus Low Open Woodland	Widespread in valley areas adjacent to claypans where surface water inflows accumulate. *Eucalyptus victrix* open woodland to woodland formations, with little to no understorey to a dense overstorey of *Acacia distans*. Other notable shrub species can include *A. stenophylla, A. tetragonophylla* and *Duma florulenta*. Maia (2022) noted that in some areas the understorey is impacted by current and historical grazing. Vegetation water sources comprise direct rainfall augmented by surface water inflows. Vegetation density is likely to positively correlate with soil depth and a larger relative contribution of surface inflows to soil water replenishment (topographically controlled).
ASL(1): Acacia Tall Sparse to Open Shrubland	Associated with the Jamindie Land System, at the base of alluvial fans on hardpan plains dissected by throughflow drainages. Water sources include direct rainfall and redistributed runoff. Tall Sparse to Open mixed Shrubland mainly of *Acacia synchronicia*, *A. tetragonophylla*, *A. xiphophylla* with a mixed Sparse Chenopod Shrubland and occasional patches of mixed Tussock Grasses. These are generally regarded as shallow rooted, drought tolerant species.
ASL(2): Acacia Tall Shrubland	Associated with creek banks, minor drainage channels and floodplains. *E. victrix* is present as scattered trees (low density). Other notable species include *Corymbia hamersleyana, A. tumida* var. *pilbarensis*, *A. pyrifolia* and *A. maitlandii* and the understorey tussock grass *Themeda triandra.* Vegetation water sources comprise direct rainfall augmented by drainage inflows, with soil water storage controlled by alluvium depth. Vegetation density is likely to positively correlate with soil depth.
AWL(1): Acacia Low Woodland or Tall Shrubland	A spatially extensive vegetation types that occurs on stony, washout flats with indistinct drainage on the northern side of the Fortescue Valley. Distinct banded vegetation formations supported by localised surface water redistribution processes. Dominated by *Acacia aneura* (complex) - shallow rooted, drought tolerant species.
AWL(2): Acacia Low Woodland or Tall Shrubland	Similar to AWL(1), but mostly occurs on the southern side of the Fortescue Valley on better developed alluvial fans. Vegetation banding is evident but less distinct that AWL(1). Major species include *Acacia aneura* (complex), *Acacia synchronicia* and *A. tetragonophylla. E. victrix* present as scattered trees (low density).
AWL(3): Acacia Low Woodland	Functionally similar to AWL(1) and AWL(2); but has a more restricted distribution. Occurs on broad drainage lines, drainage basins and hardpan and stony plains.
AxAsSL: Acacia Tall Shrubland	Principally associated with the Hooley Land System (west of the proposed mining areas), occurs mainly on hardpan and stony plains. Characterised by fine textured (clayey) soil types. Water sources include direct rainfall and redistributed runoff. Tall Sparse Shrubland of *A. xiphophylla* and / or *A. synchronicia* with a mixed Sparse Chenopod Shrubland. These are generally regarded as shallow rooted, drought tolerant species.
BpoFL: Bergia Forbland	Occurs in valley areas where surface water inflows accumulate, pool and persist. Claypan landforms mostly bare of vegetation but with scattered *Bergia perennis* subsp. *obtusifolia* and mixed tussock grasses mainly of *Eriachne benthamii* and *Sporobolus mitchellii. E. victrix* and *A. stenophylla* sometimes present as scattered trees (low density). The samphire *Tecticornia verrucosa* is a notable subordinate species.
EfEbTG: Eriachne Tussock Grassland	Occurs in valley areas where surface water inflows accumulate, on slightly raised portions of claypans. Dominated by tussock grassland of *Eriachne flaccida* and *E. benthamii. E. victrix* present as scattered trees (low density).

Vegetation Type	Key Ecohydrological Characteristics
*Ev*WL: Eucalyptus Low Open Woodland	Similar to *AdEv*WL but is restricted to areas where the river flow line is more defined. *E. victrix* occurs in open woodland formations.
Mosaic of *AdEv*WL / *Bpo*FL	*E. victrix* occurs in patchy open woodland formations within this mosaic.
MSL (1): Mixed Mid Shrubland	Occurs on low rises within the Fortescue River and surrounds and has been divided into two subunits: MSL(1) is interspersed within vegetation type AdEvWL and areas of MSL(1) that are higher in the landscape are dominated by *Triodia epactia*, while those in lower areas are dominated by tussock grasses. *E. victrix* present as scattered trees (low density). Subject to infrequent flooding.
MSL (2): Mixed Tall Shrubland	
MTG (1): Mixed Tussock Grassland	Occur on alluvial plains adjacent to major drainages feeding into the Fortescue Valley. Characterised by fine textured soils. *E. victrix* present as scattered trees (low density) in MTG(1) and MTG(2).
MTG (2): Mixed Tussock Grassland	
MTG (3): Mixed Tussock Grassland	
THGB: Triodia Hummock Grassland on Basaltic Terrain	Occurs on level to very gently inclined basaltic plains in the Chichester Range. Characterised by gilgai microrelief and clay soils.
*Tl*HG (1): Triodia Hummock Grassland	Occur on hillslopes in the Chichester Range. Rainfed, shallow rooted vegetation growing on stony soils.
*Tl*HG (2): Triodia Hummock Grassland	
*Tv*HG: Triodia Hummock Grassland	Has a restricted distribution on low rolling hills and undulating stony plains with a surface layer of shale in the Chichester Range. Rainfed, shallow rooted vegetation growing on stony soils.

7.8 2023 Site Inspection Observations

Figure 7.8 presents the area covered by the 2023 site inspection, together with the locations of selected observations / photographs referenced below.

7.8.1 Geomorphology

The major geomorphic units in the 2023 AOI include:

- The foothills of the Chichester Range (slope > 1%).
- The gently sloping alluvial fans between the foothills and the Fortescue Valley (slope approx. 0.3%).
- The Fortescue Valley flats (slope <0.1%).

Note that terrain slope is an important discriminator and major determinant of landscape hydrological behaviour in the AOI.

Within the major geomorphic valley units, further segregation can be made on the basis of surface drainage type (channelised flow vs sheet flow), surface roughness (affecting rainfall storage) and surface infiltration behaviour. Patterns of vegetation and soil are related to these characteristics consistent with the following principles (Ross et al. 2021; Nouwakpo et al. 2016; Pierson and Williams 2016; Tongway and Hindley 2004):

- Water arriving at the ground surface during rainfall events either evaporates, ponds at the soil surface, is stored in the litter layer, infiltrates into the soil, or is transferred downslope as runoff.
- By virtue of the rainfall storage characteristics of the land/vegetation surface, runoff generation exhibits threshold behaviour. Runoff only occurs when surface storage is exceeded.
- Surface storage is not a static parameter; rather at any point in time it constitutes a dynamic equilibrium between water inputs, storage and outputs. This makes the prediction of runoff behaviour complex and difficult. Key parameters affecting runoff are rainfall depth, rainfall intensity and antecedent conditions affecting surface storage at the time of rainfall (e.g. soil moisture).

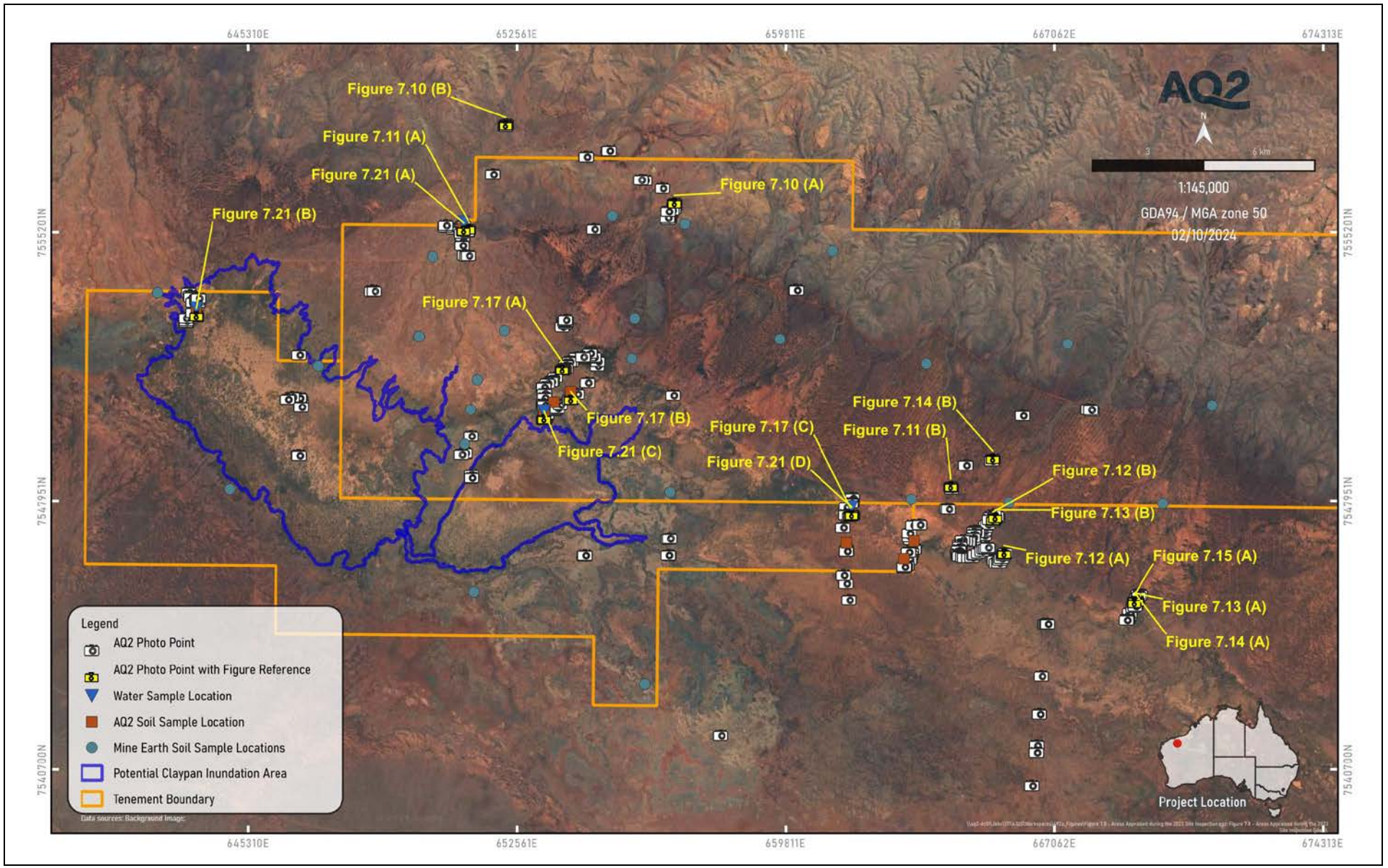


Figure 7.8 Areas Appraised during the 2023 Site Inspection

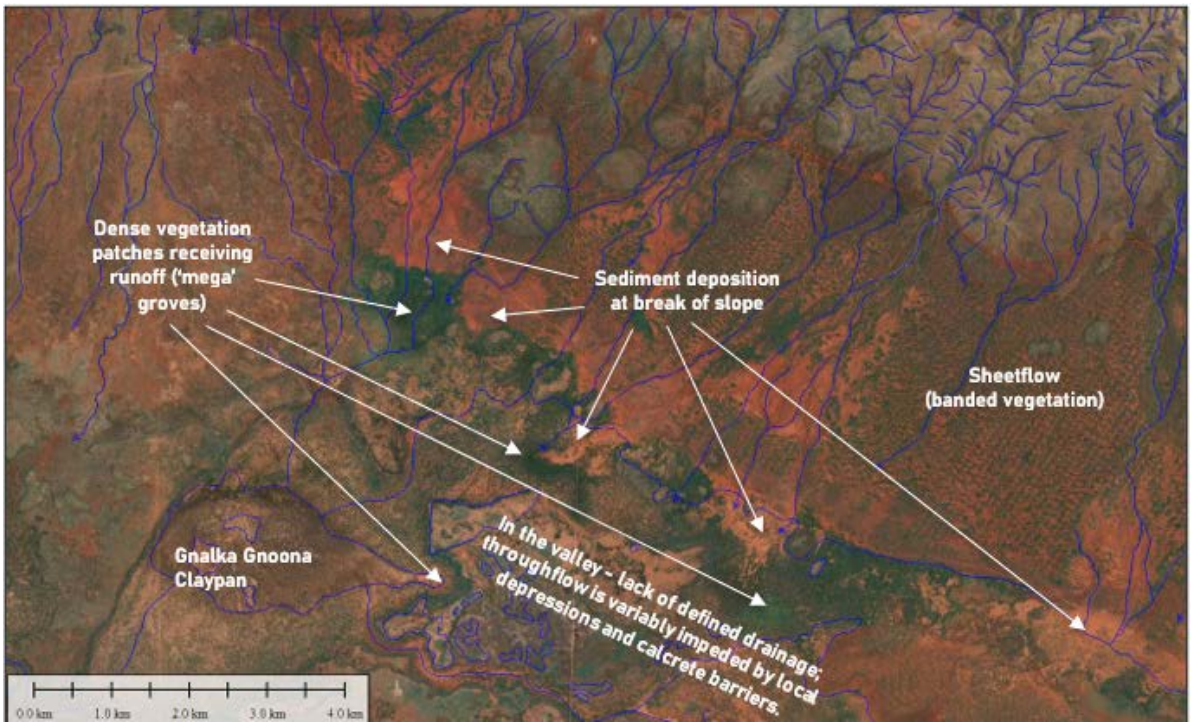
- Runoff occurs more rapidly after the onset of rainfall in sparsely vegetated interspaces than in vegetated zones, because vegetated areas generally have greater rainfall storage capacity. Factors contributing to this include:
    - Higher storage – by virtue of 3-dimensional structure, vegetated surfaces have a greater surface area facilitating physical entrapment of rainfall.
    - Infiltration losses in vegetated and litter covered areas are generally higher due to increased organic matter and biological productivity. Organic contributions and soil fauna activity contribute to lower soil bulk density, increased macropore development and other soil physicochemical properties associated with enhanced infiltration.
- Collectively, interception and enhanced infiltration in vegetated areas commonly results in two- to more than 20-fold less event runoff relative to bare or sparsely vegetated areas across point to patch scales. As a consequence, water and nutrients tend to translocate from bare (source) areas to adjacent vegetated (sink) areas. In water limited environments, this gives rise to vegetation patchiness that is re-enforced by a positive feedback of rainfall redistribution to sink areas.
- Vegetation degradation tends to reduce flow path tortuosity and increase runoff connectivity, with an associated increase in erosive energy and soil loss. Where pronounced, this can lead to a transition from sheet flow dominated to focused (i.e. channelised flow path) dominated water movement.

Considering these principles, the key geomorphic elements observed in the AOI were as follows:

- The Chichester Range Uplands comprising:
    - Rocky hilltops and slopes – water source areas characterised by skeletal soils vegetated with spinifex.
    - Infill valleys – areas between the rises where alluvium/colluvium has accumulated. The deeper soils provide for increased plant available water storage and thus support denser vegetation (typically *Acacia* shrublands).
- Drainage channels – ephemeral river channels that receive inputs from the surrounding uplands and transmit flows onto the alluvial fans. The upland drainages conform with the 'unconfined/semi-confined single thread cobble channel' geomorphic type, as described by Flatley et al. (2022; 2023) for Pilbara headwater streams. Gravel bars were prominent in the channels, which provide resilience to flood disturbance by increasing hydraulic roughness. Channel migration is ultimately confined by basement highs, and many of the channels are skewed to one edge of their host valleys.
- The Alluvial Fans comprising:
    - Wide, gently sloping interfluves with stony surfaced soils and banded vegetation formations. Water redistribution processes are dominated by localised sheetflow, transferring from sparse intergroves to adjacent vegetated groves. In small to medium sized rainfall events, rainfall is likely to be retained within this element. In large rainfall events, excess water may be delivered into adjacent drainage tracts.
    - Drainage tracts characterised by small low flow channels (circa 1 to 3 m wide and 30 to 50 cm deep) and narrow vegetated floodplains. These are principally fed by the drainage channels existing the Chichester Range uplands, transmitting flows through to the valley flats which otherwise bypass the alluvial fan geomorphic unit. In general, channel depths are constrained by hard, high bulk density subsoils. Flows within these drainage channels progressively lose energy moving from alluvial fan apex to toe, and completely dissipate where they enter the Fortescue Valley flats.

- The Fortescue Valley Flats comprising various units chiefly distinguished by surface soils / microtopography:
  - Stony flats – these areas are most prominent on the outer flanks of the Fortescue Valley. Near the drainage termini from the alluvial fans, the stony flats are commonly blanketed with a veneer of fine sediments. This fine sediment accumulation is probably a natural process but may have been exacerbated by a prolonged history of cattle grazing causing erosion on the alluvial fans. Infiltration is impeded, resulting in periodic waterlogging and near surface salt accumulation in small depressions within a wider micro-topographical mosaic. The vegetation is generally sparse, attributable to limited infiltration and soil water replenishment.
  - Loamy flats – these areas are associated with the better developed *E. victrix* woodlands and tussock grasslands of the Fortescue Valley. Soil characteristics are inferred to be influenced by organic matter accumulation; the surficial soils exhibit a high degree of macropore development and variable shrink-swell behaviour associated with clay content. Functionally, the loamy flats can be regarded as 'mega-groves' within a patched vegetation landscape, which receive runoff from either the adjacent alluvial fan geomorphic unit or calcrete rises within the Fortescue Valley itself. The density of trees and grasses is variable and appears to correspond with soil type and runoff delivery niches.
  - Calcrete flats and rises – these comprise benches or rises of calcrete formed in the Fortescue Valley in the Neogene (late Tertiary) period. The calcrete sometimes outcrops, but otherwise is overlain by shallow loamy soils formed in-situ and/or blanketed by shallow layers of valley alluvium. The upper surface of the calcrete has been generally softened by weathering and becomes harder and massive with depth.
  - Calcrete is commonly found in paleovalleys of arid Australia, and forms within valley sediments by precipitation of carbonate near the water-table and upward displacive growth (Chen et al. 2002). In the Pilbara region, valley calcretes typically comprise thick and expansive hardpans associated with groundwater systems upgradient of throughflow impediments such as basement pinch points or intrusive barriers. Calcrete has been intersected in all hydrogeological drilling in the valley of the AOI and, given the relationship between calcrete formation and groundwater, calcrete would be expected to extend across the full width of the Fortescue Valley Flats (i.e. beyond the AOI, to the south).
  - Ponding flats – these areas are formed in topographic depressions with high clay content soils that restrict infiltration, resulting in periodic waterlogging and near surface salt accumulation. The ponding flats are largely non-vegetated. Ponding water is derived from direct rainfall augmented by runoff inputs. Source catchments are difficult to define owing to lack of defined drainage and overall flatness of the Fortescue Valley. The most prominent examples are the Gnalka Gnoona and Koodjeepindarranna claypans; however, in the AOI smaller claypan features that function similarly are scattered throughout the valley.

Landscape relationships between these geomorphic units are schematically described in Figure 7.9. Photographic examples of each geomorphic element are provided in Appendix N.



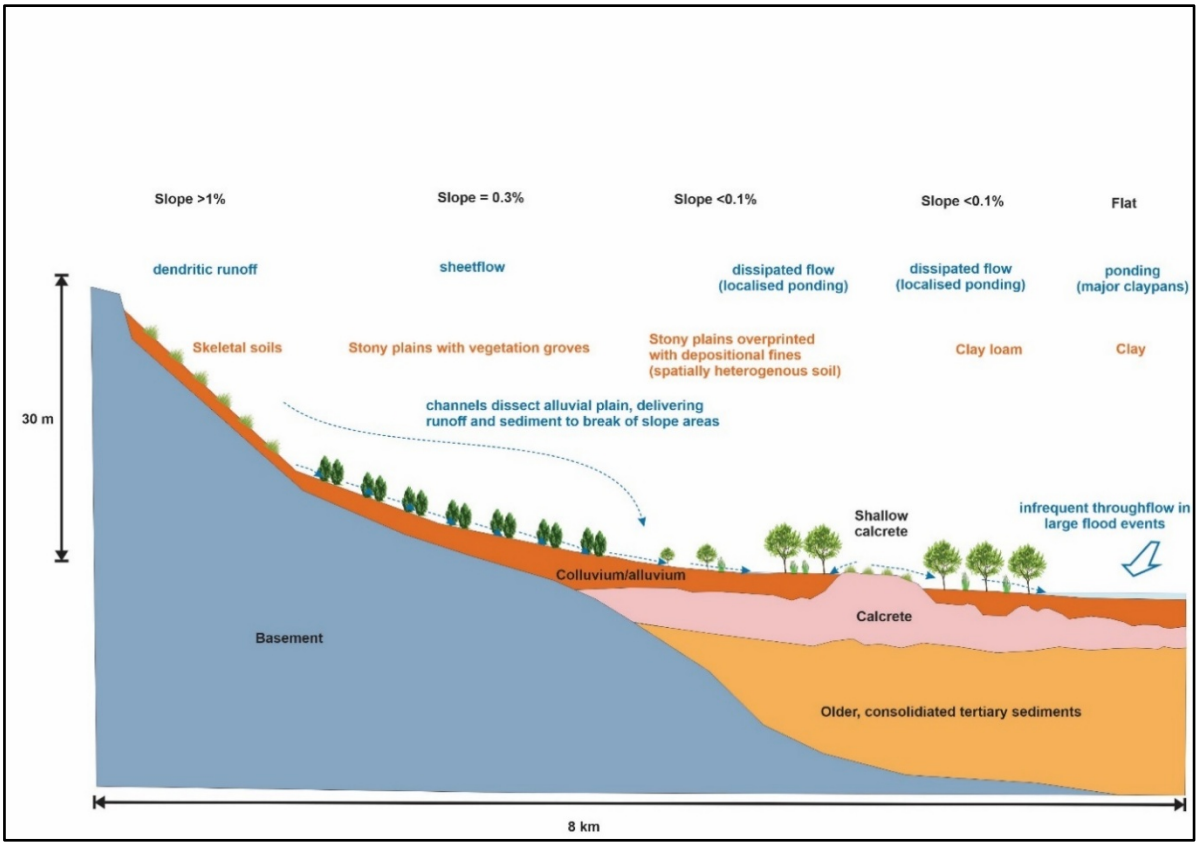


Figure 7.9 Key Geomorphic Features in the Area of Interest (blue lines show indicative flow paths)

7.8.2 Soil and Vegetation

The interpretation of soils during the site visit included consideration of surface attributes and soil profile exposures in drainage line exposures, erosion rills and open sump pits associated with drilling programs.

Key observations and inferences from the Chichester Range Upland unit were as follows:

- Upland valley profiles associated with drainages comprised earthy soils with a variable but significant proportion of sub-rounded to sub-angular coarse fragments. In some cases, the gravel/cobbles were concentrated in bands, reflecting historical variation in flow energy (Figure 7.10).
- The channel beds mostly comprised cobble beds, which form a protective barrier to deeper incision. This effect is enhanced by the high bulk density of the iron rich cobbles (Flatley and Rutherford 2023). However, gravel bars can contribute to side cutting of banks and this was observed at multiple locations (refer Appendix N).
- Small-scale channel aggradation (e.g. the pulsing of finer sediment and creation of small nascent bar forms) is an ongoing, dynamic process in the channels.
- The channels are fringed by widely spaced, mature *E. victrix* trees. This open woodland structure is indicative of limited soil volume/plant available water storage, which constrains the carrying capacity of the woodland.

Key observations and inferences from the Alluvial Plain unit were as follows:

- The soils of the interfluves are mantled by well-developed stony pavements (Figure 7.11). These surfaces require long term geomorphological stability to develop (i.e. minimal fluvial reworking). The soil profile typically includes poorly sorted gravel; however, a finer textured A horizon develops beneath the surface pavement, via aggradation of fine sediments and dust (Figure 7.12). These surfaces are vulnerable to erosion if the gravel mantle is disturbed, and historical disturbance most likely resulting from cattle was observed at multiple locations in the AOI (Figure 7.13).
- The drainage tracts include a deeper, well-structured A horizon deriving from fluvial deposition (Figure 7.14). In comparison with the interfluve areas, these soil profiles have favourable infiltration and soil water storage characteristics and support denser vegetation dominated by mulga.
- In a few places the hard subsoil underlying the alluvial fan was exposed (Figure 7.15).
- Consistent with the observations made by Mine Earth (2021), the subsoil is typically about 50 cm below the ground surface and comprises hard and massive (poorly structured) clay. This subsoil clay can be putatively classified as a red–brown hardpan; a common regolith material in gently inclined slopes and plains of the Australian arid interior that is variably indurated by iron oxides and hydroxides, and amorphous silica (Thiry et al. 2006; Anand and Paine 2002).
- As general rule within inland Australia: the soils of the intergrove and grove areas tend to be chemically distinct (Macdonald et al. 2015). Soluble salts become concentrated in the intergrove soils, resulting from the limited infiltration and subsequent redistribution of runoff water into the grove soils. Sodium and chloride concentration gradients 10–100-fold have may develop between the groves and intergroves. Nitrate also accumulates in intergrove soils owing to limited biological activity, but in contrast is depleted by vegetation uptake in grove areas. Although not directly measured, it is likely that the alluvial plain soils in the AOI exhibit these characteristics.
- Key observations from the Fortescue Valley Flats unit were as follows:
    - The soils of the Stony Flats are somewhat analogous to the Alluvial fan interfluves, the key difference being that the slope is insufficient to permit the development of banded vegetation formations. Soil salinity on the Stony Flats is higher owing to the reduced lateral movement of water. In high intensity rainfall events, these surfaces may transmit water to adjacent Loamy Flats areas via the development of contrasting depths in ponded head caused by infiltration rate differences (Thompson et al. 2011). In general, areas with the highest salinity correspond with topographic lows.

  - The Mine Earth (2021) test pit at location ME17 provides an example of the soil profile for the Stony Flats (Figure 7.16). Note that this profile was classifiable as extremely saline based on the reported EC1:5 values (1.77 dS/m at 10-20 cm; 3.82 dS/m at 40-50 cm; 3.47 dS/m at 90-100 cm). High near surface nitrate-N (73 mg/kg at 10-20 cm; 155 mg/kg at 40-50 cm; 24 mg/kg at 90-100 cm) and subsoil sulfur (1,411 mg/kg at 90-100 cm) values were also recorded at this location. Collectively, these results are suggestive of impeded percolation and flushing. It is speculated that the high soil Sulfur levels may derive from aeolian dust that has been washed in from the upgradient alluvial plains over geological time.
- Calcrete flats and rises:
  - The defining feature of these soils is shallow calcrete (within about 50 cm of the surface). This restricts vegetation rooting depth and exposes the vegetation to drought stress during extended dry periods. In the shallowest soils, the vegetation is dominated by drought tolerant spinifex species. Greater soil depth allows a wider variety of shrub and tree species to persist.
  - As soil depth increases, this unit transitions into the Loamy Flats unit.
- Loamy Flats:
  - Notable features of these soils include high surface roughness and better soil structure than other units, which facilitates high infiltration and plant available water storage. Consequently, these soils support higher vegetation density and rates of organic matter cycling. Subsoils (below about 50 cm depth) become harder and less permeable (i.e. similar to the Stony Flats soil). These soils overlie calcrete within a few meters of the surface.
- Ponding Flats:
  - The soils of the Ponding Flats are inferred to be somewhat similar to those of the Stony Flats; with key differences being a less developed or absent stony mantle, even lower permeability and consequently higher accumulation of salts closer to the surface.
  - The Mine Earth (2021) test pit at location ME18 provides an example of the Ponding Flats soil profile. Note that this profile was classifiable as extremely saline based on the reported EC1:5 values (7.65 dS/m at 10-20 cm; 5.39 dS/m at 40-50 cm; 4.54 dS/m at 90-100 cm). High near surface nitrate-N (48 mg/kg at 10-20 cm; 19 mg/kg at 40-50 cm; 3 mg/kg at 90-100 cm) and plant-available sulfur throughout the profile (1,731 mg/kg at 10-20 cm; 1,744 mg/kg at 40-50 cm; 1,473 mg/kg at 90-100 cm) values were also recorded at this location. Mine Earth (2021) noted the occurrence of gypsum crystals (2-10 mm in size) in this profile. Collectively, these results are suggestive of impeded percolation and flushing.
  - The sparse vegetation comprises species with special adaptations to salinity, waterlogging and inundation.

The Mine Earth (2021) soil physicochemical data was reinterpreted based on the geomorphic units described in Section 3.2.1 (refer Appendix O). Plots of conductivity (EC1:5), Nitrate-N and plant-available Sulfur vs depth are shown in Figures 7.11, 7.12 and 7.13 respectively. Although based on a small sample size, these findings affirm the following general inferences:

- Soils of the alluvial fan interfluves are non-saline, with Nitrate-N accumulation in the subsoil indicative of minimal vegetation root uptake and minimal flushing. This is consistent with these surfaces shedding runoff to adjacent areas.
- Soils of the Calcrete Plains and Loamy Flats exhibit an increase in salinity with depth (moderately saline subsoils), relatively high near surface Nitrate-N likely associated with organic matter inputs from decomposing litter and lower subsoil Nitrate-N from vegetation root uptake. Increasing plant-available Sulfur at depth likely reflects impeded deep flushing caused by soil water depletion by vegetation in the overlying soil layers.

- Soils of the Stony Flats and Ponding Flats are very to extremely saline, resulting from restricted drainage/flushing and evaporative concentration of salts. These soils are not favourable for vegetation, which is sparse. Nitrate-N accumulates due to minimal biological activity and a lack of flushing; this being more pronounced at shallow depth in the Ponding Flats. Plant-available Sulfur is very high in the subsoils, which is also indicative of impeded flushing. By virtue of being in the lowest topographic positions, the Ponding Flats experienced the most sustained ponding and evaporation.

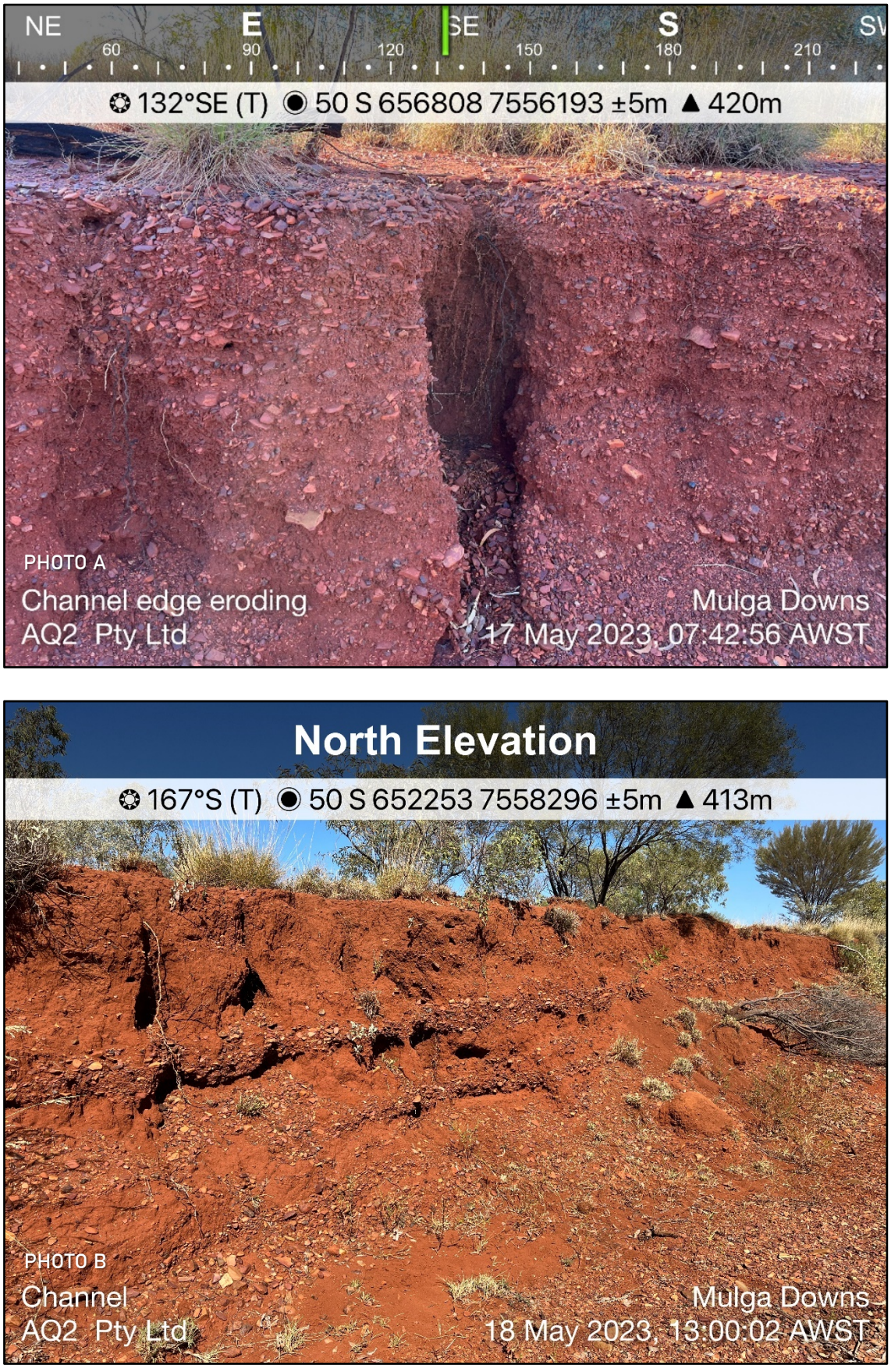


Figure 7.10 Soil Profiles in Valley Drainages of the Chichester Range Uplands

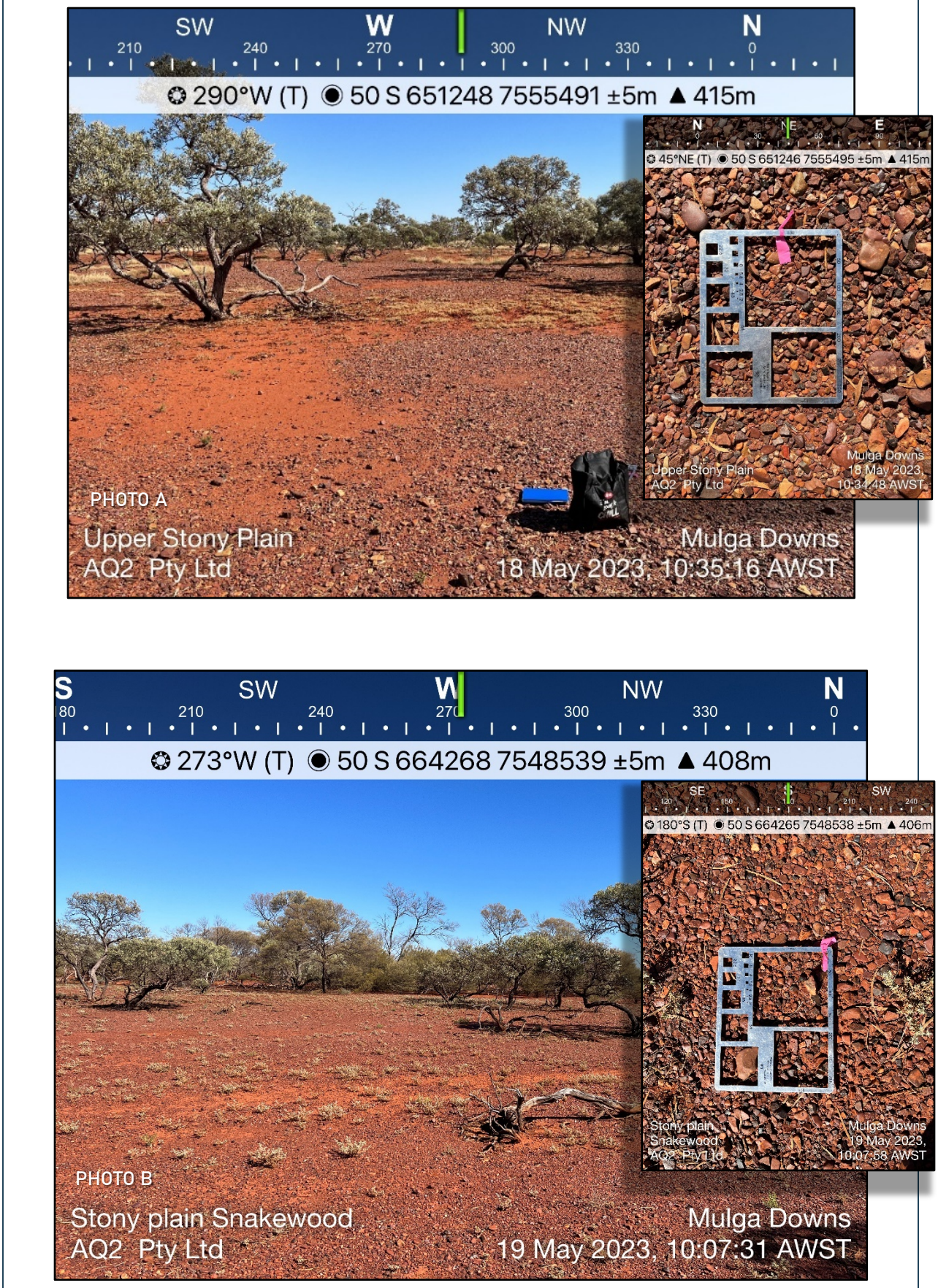
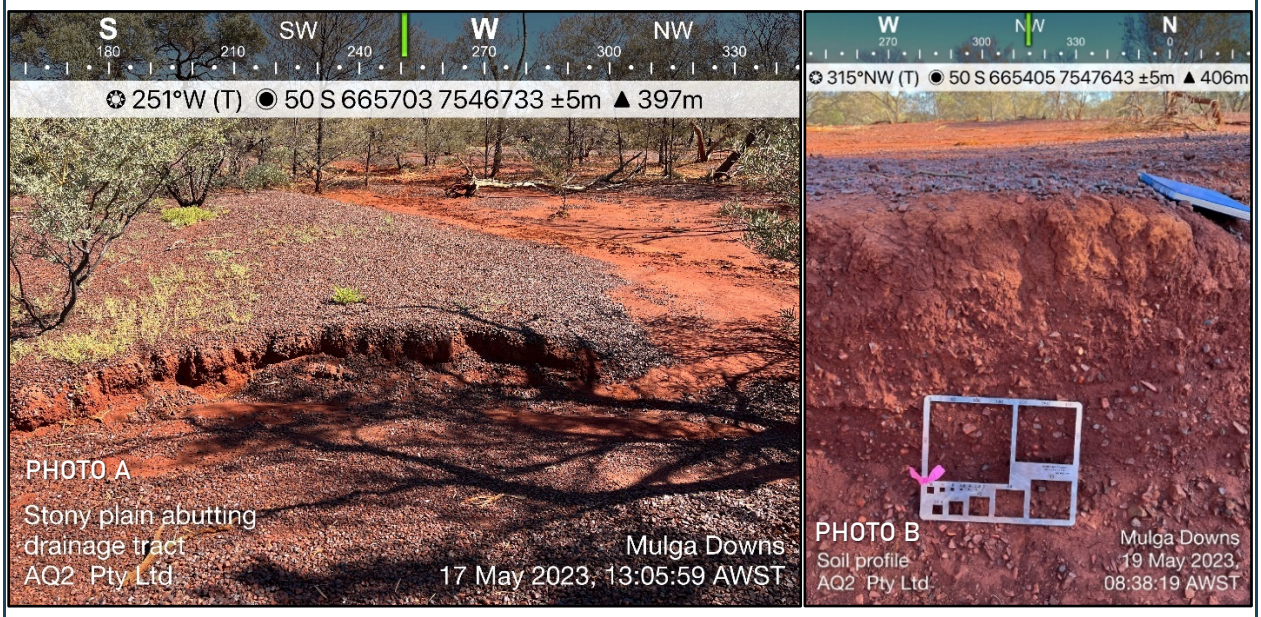


Figure 7.11 Stony Pavements of the Alluvial Fan interfluves



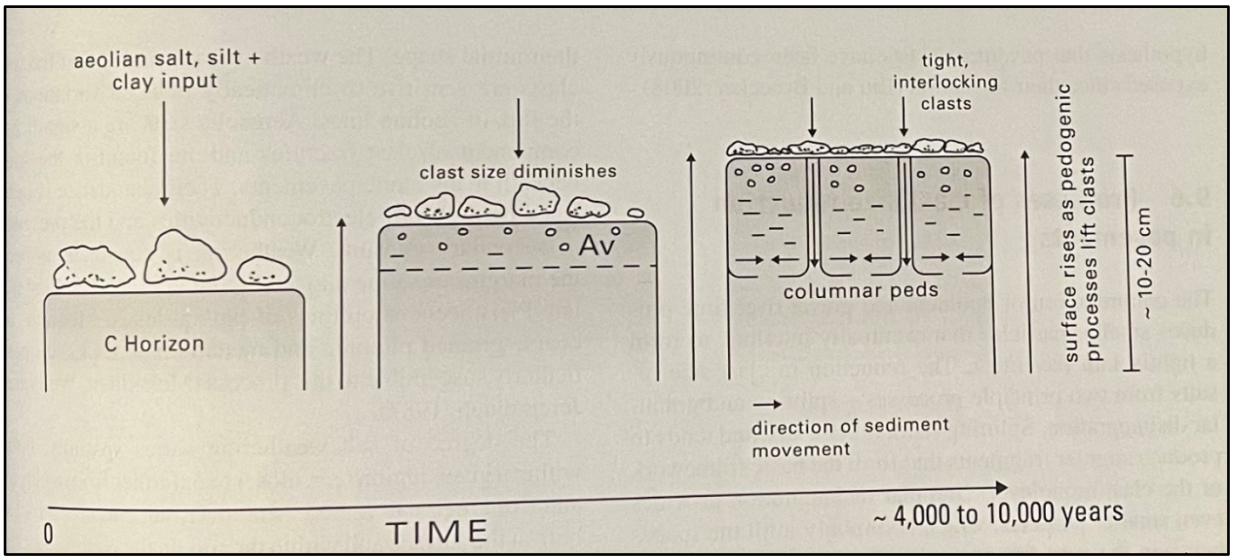
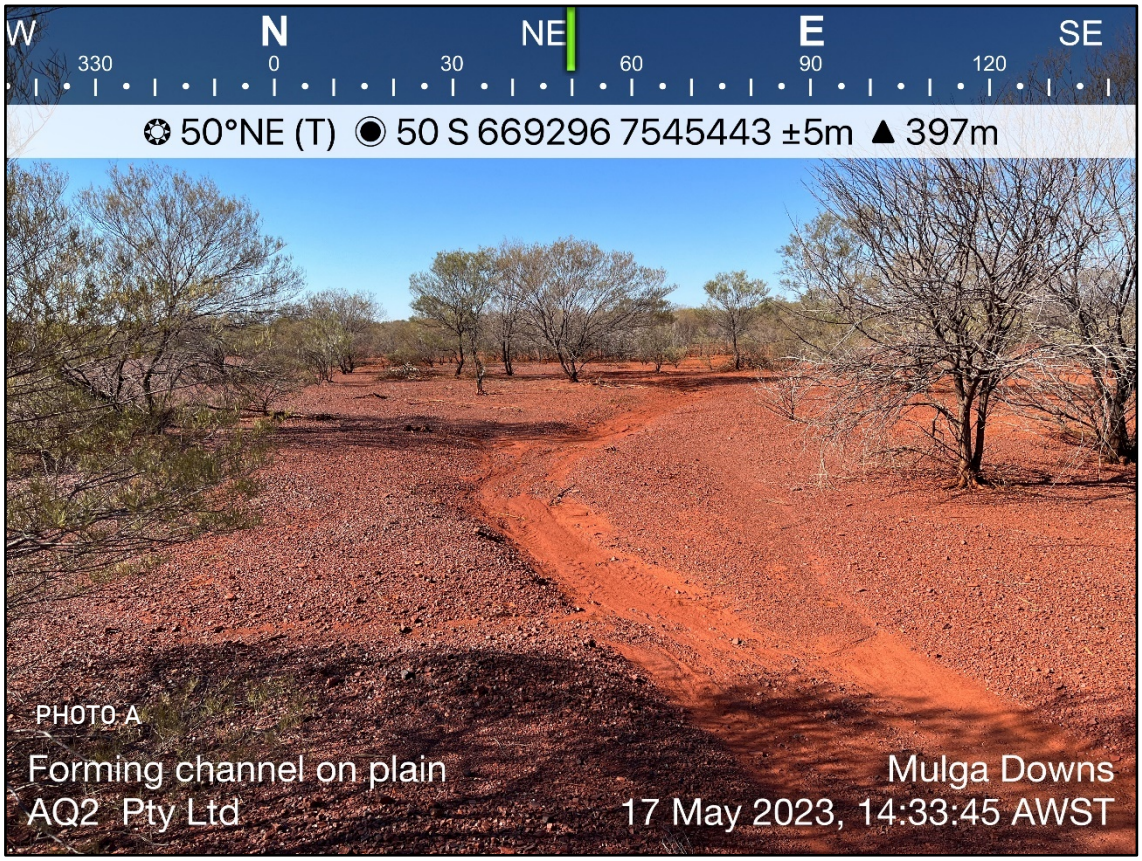


Figure 7.12 Stony pavement formation with aggradation of fines beneath the surface pavement (bottom: schematic reproduced from Thomas (2011))



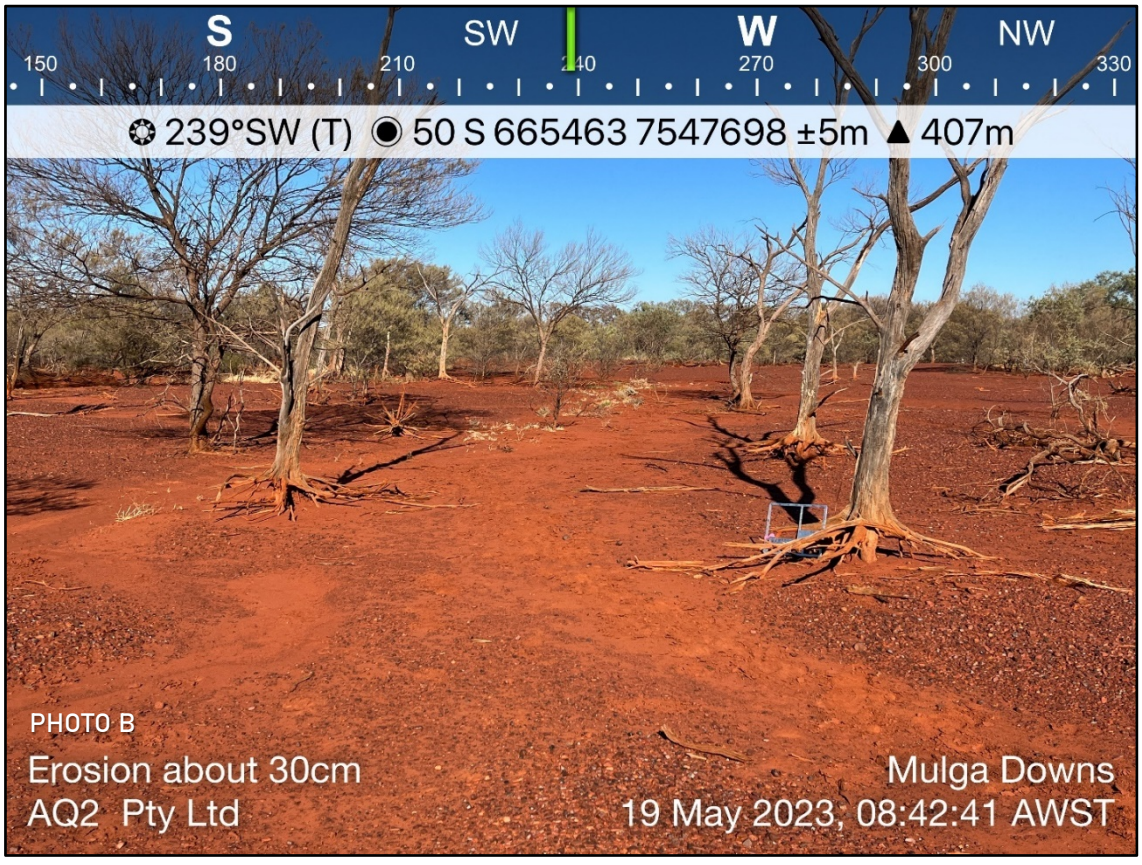


Figure 7.13 Examples of Erosion of the Stony Pavement on the Alluvial Fans

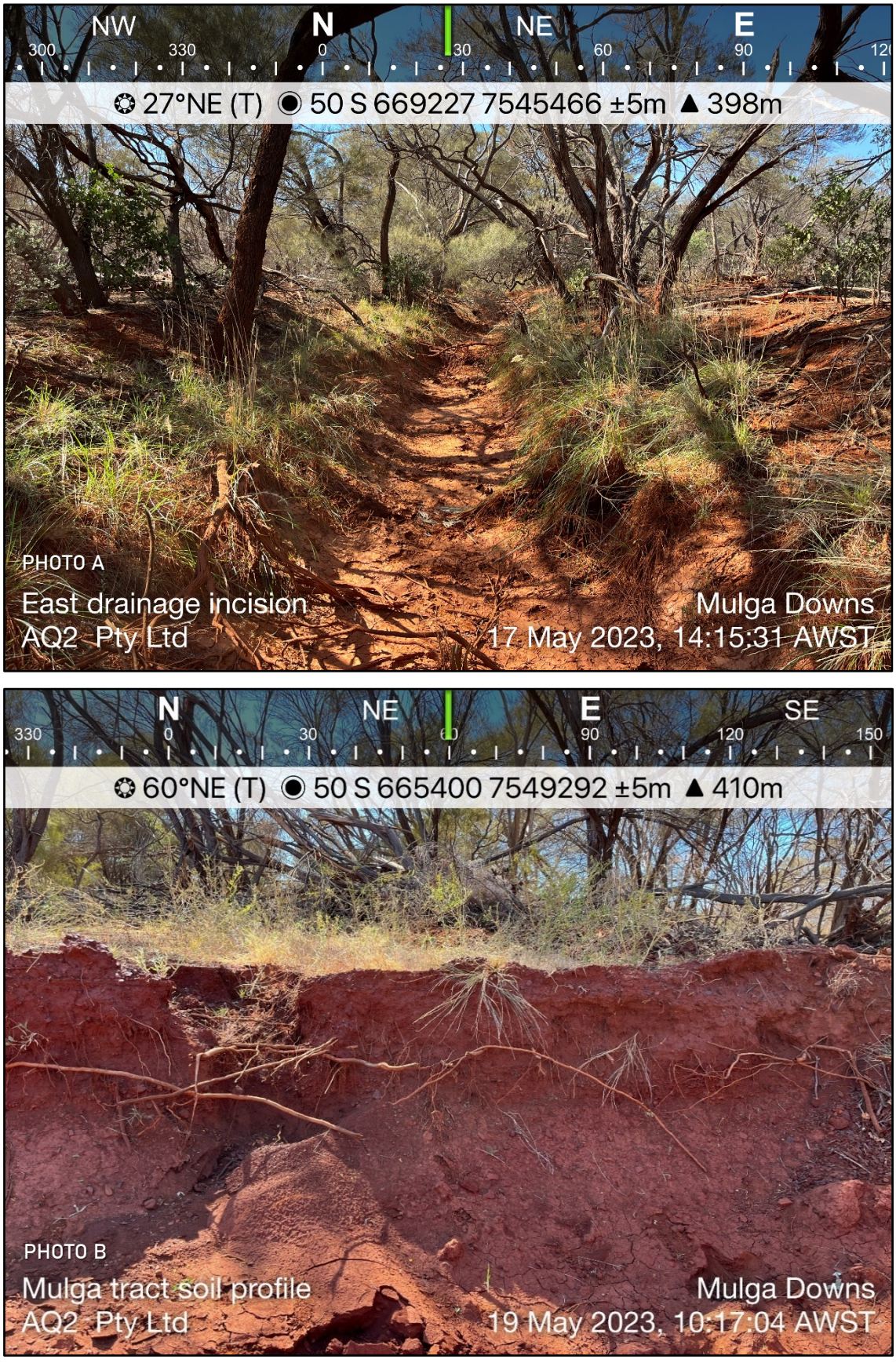


Figure 7.14 Soil Profiles of the Alluvial Plain Interfluves



Figure 7.15 Hard Subsoil exposed by Erosion in an Alluvial Fan Drainage Tract

Site Reference:	Mulga East Site ME17	**Datum:**	GDA 1994 MGA Zone 50
Site Description:	Broad stony alluvial plain	**Easting:**	652219
Soil Landform Association:	Floodplain	**Northing:**	7552541



Soil profile description:

0-60 cm: Moderately structured soil with polyhedral aggregates of moderate strength, to 50 mm in size. Approximately 20% sub-angular to sub-rounded coarse fragments, 2 to 20 mm in size.

60-120 cm: Massive soil structure with 10% ironstone nodules, 2 to 30 mm size.

Plate 33 Surface soil profile at Site ME17

Soil surface: Very thin platy surface crust, with approximately 80% cover of angular to sub-rounded coarse fragments at surface, 2 to 75 mm in size, with < 2% litter cover. Minor areas of deposition and erosion from sheet flow but no obvious drainage channels.

Vegetation: Mostly bare stony surface with scattered Acacia trees (2 to 3 m) and patches of grasses.



Plate 34 Landscape / vegetation at Site ME17

Figure 7.16 Example soil profiles characteristics of the Stony Flats landscape element (reproduced from Mine Earth 2021)

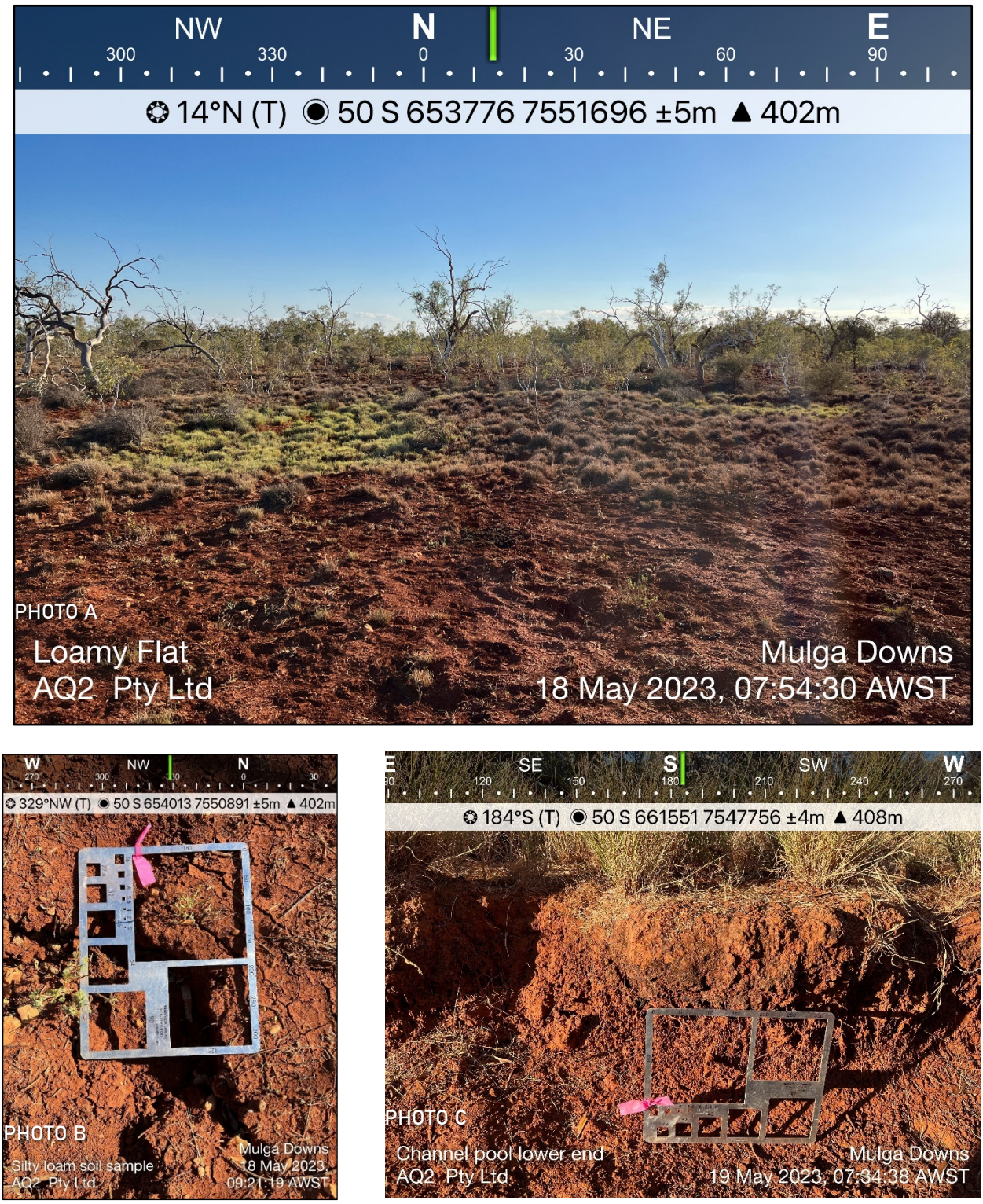
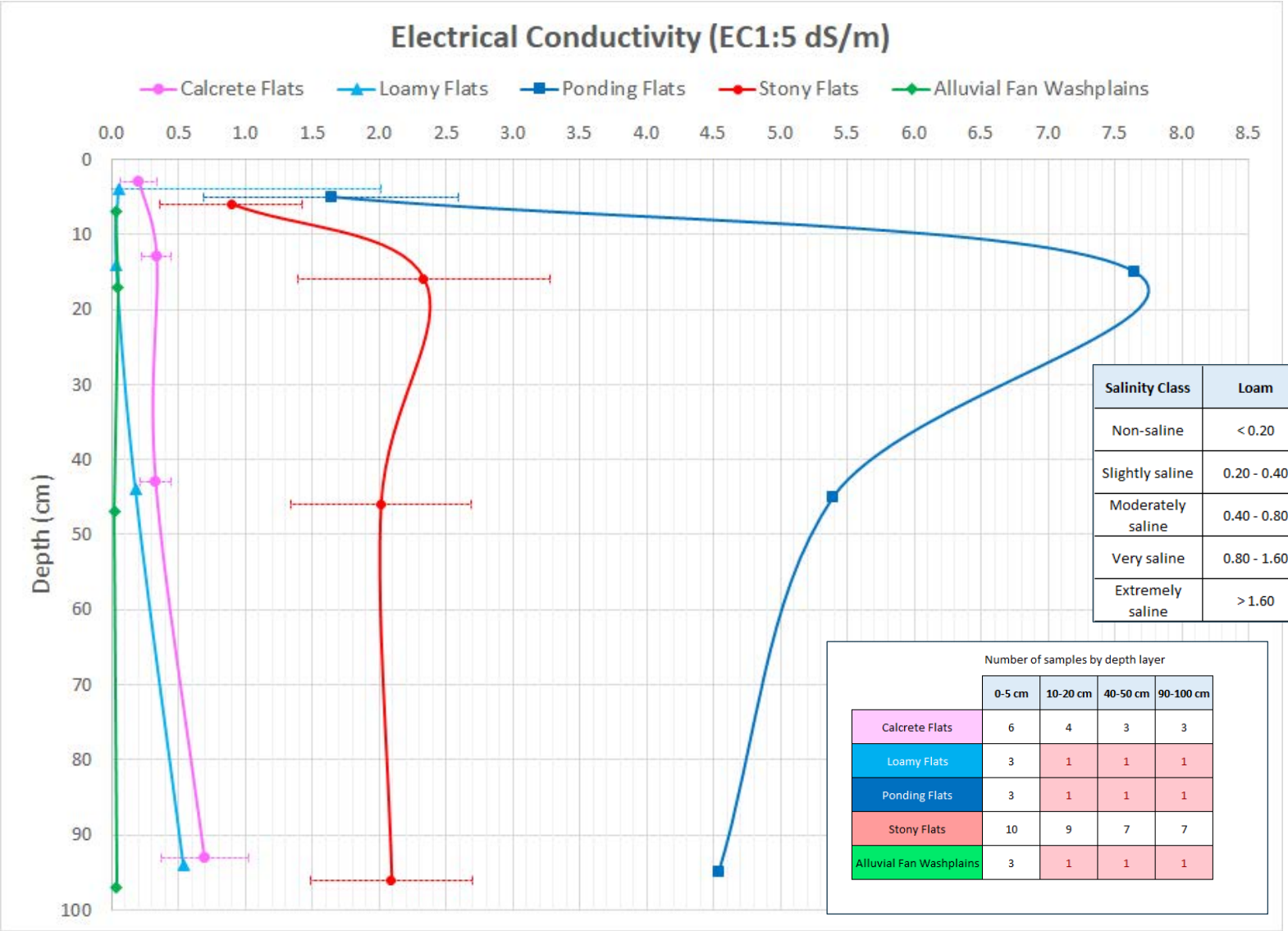


Figure 7.17 Soil Features of the Loamy Flats Landscape Element

Note pronounced microtopographic roughness (top); with patches of green grass associated with moisture accumulation in small depressions. High surface storage and infiltration is facilitated by cracks and macropores.

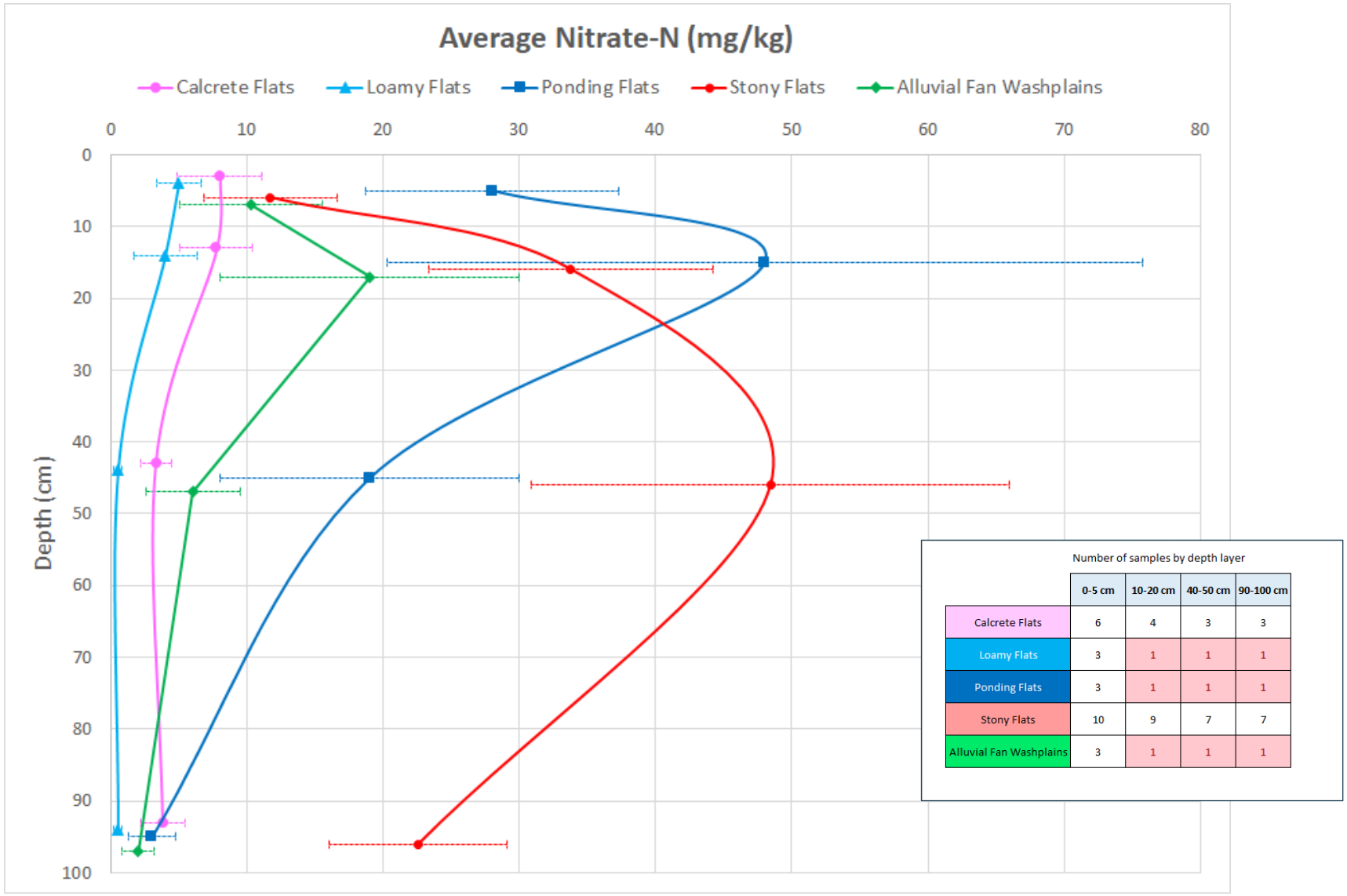


Salinity Class	Loam	Light/med. clay
Non-saline	< 0.20	< 0.22
Slightly saline	0.20 - 0.40	0.22 - 0.44
Moderately saline	0.40 - 0.80	0.44 - 0.89
Very saline	0.80 - 1.60	0.89 - 1.78
Extremely saline	> 1.60	> 1.78

Number of samples by depth layer

	0-5 cm	10-20 cm	40-50 cm	90-100 cm
Calcrete Flats	6	4	3	3
Loamy Flats	3	1	1	1
Ponding Flats	3	1	1	1
Stony Flats	10	9	7	7
Alluvial Fan Washplains	3	1	1	1

Figure 7.18 Average Electrical Conductivity of Soils of Different Geomorphic units in the Area of Interest



	0-5 cm	10-20 cm	40-50 cm	90-100 cm
Calcrete Flats	6	4	3	3
Loamy Flats	3	1	1	1
Ponding Flats	3	1	1	1
Stony Flats	10	9	7	7
Alluvial Fan Washplains	3	1	1	1

Figure 7.19 Average Nitrate-N of soils of Different Geomorphic Units in the Area of Interest

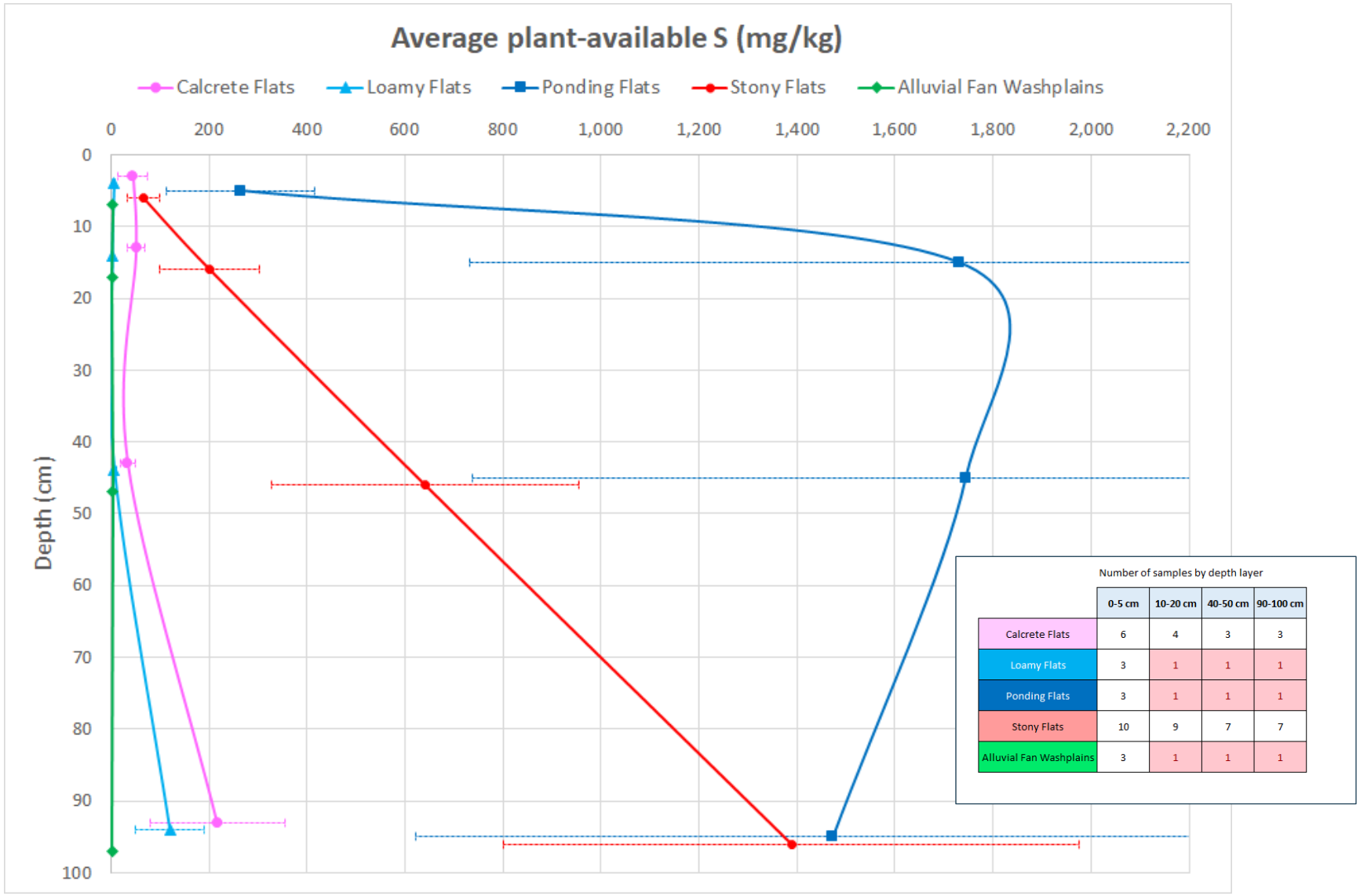


Figure 7.20 Average Plant-available Sulfur of soils of Different Geomorphic Units in the Area of Interest

7.8.3 Water Samples

Where ponded water was encountered during the May 2023 site visit, opportunistic sampling was undertaken. The sampling gave the following in-field results using a Multi-parameter TESTR 35 portable meter:

- Pool in alluvial fan drainage channel, north of Koodjeepindarranna Claypan (651118E; 7555469N):
  - Water temperature (11.00am) = 16.9 ^{0}C
  - EC = 242 µS/m
  - TDS = 133 ppm
  - pH = 7.6
- Pool in clayey depression in the Koodjeepindarranna Claypan environs (643902E; 7553142N):
  - Water temperature (1.45pm) = 26.4 ^{0}C
  - EC = 210 µS/m
  - TDS = 115 ppm
  - pH = 7.4
- Pool in clayey depression north of Gnalka Gnoona Claypan (653289E; 7550364N):
  - Water temperature (8.30am) = 14.0 ^{0}C
  - EC = 340 µS/m
  - TDS = 186 ppm
  - pH = 8.1
- Pool in clayey depression east of Gnalka Gnoona (661589E; 7547774N):
  - Water temperature (7.40am) = 12.8 ^{0}C
  - EC = 191 µS/m
  - TDS = 105 ppm
  - pH = 7.5

Photographs of the water sampling locations are shown in Figure 7.21 (co-ordinates are shown on the photos for correlation with data above).

In all cases, the ponded water was relatively fresh and low in dissolved solids suggesting it derives from fairly recent rainfall. There was evidence of recent cattle activity around the Fortescue Valley pools, which is presumed to have contributed to high turbidity in these pools.





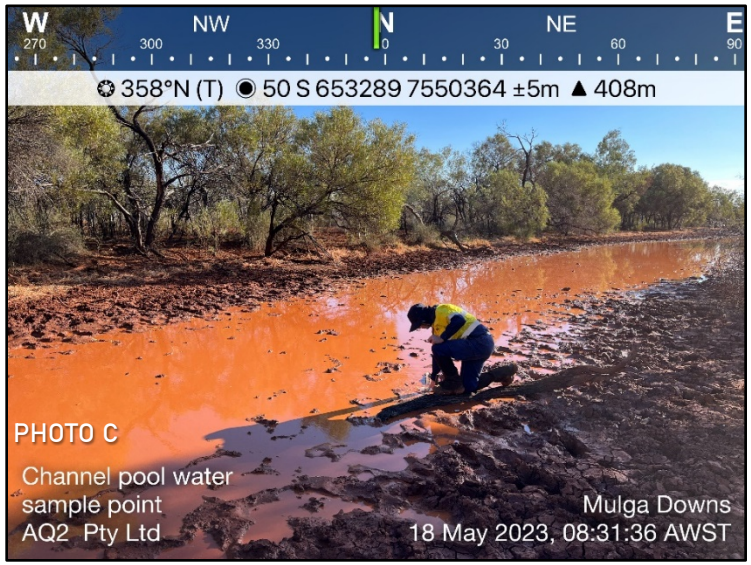




Figure 7.21 Ponded Water Sampling in May 2023

7.9 Remote Sensing Data Interpretation

Sentinel-2 imagery sourced from Sentinel Hub Earth Observation browser (https://services.sentinel-hub.com) was used to further evaluate landscape behaviour through time. Time series Normalised Difference Vegetation Index (NDVI) imagery for the period November 2019 to May 2023 was evaluated, which spanned several wetting and drying cycles. This imagery is provided in Appendix P, which also includes boundaries for derived landscape ecohydrological units (further discussed in Section 8).

The NDVI detects photosynthetically active biomass and is a widely used indicator of vegetation density, vigour and changes in vegetation patterns. NDVI values vary between -1 and +1, typically ranging between 0.1 and 0.7 for vegetation in Australia[3]. Higher values are associated with greater density and 'greenness' of the plant canopy and values decrease as plants become water stressed, diseased or perish. NDVI values <0 are indicative of waterbodies.

Salient findings of the NDVI imagery interpretation are:

- There are clear differences in NDVI time series between different landscape units.
- In the Chichester Range Uplands, activation of the dendritic drainage networks promotes increased greenness within the network flow lines. On the hills and crests, the greenness trend is one of short pulses between long periods of relatively low greenness. In the drainage network, greenness persistence is variable but in general progressively reduces with time since rainfall. Zones of the highest and most persistent greenness are associated with the major drainage channels. This is consistent with a mechanism of soil water replenishment and progressive depletion by vegetation. It can be inferred that greater soil depth (a proxy for plant available water storage capacity) occurs in the channel floodplain zones.
- In the Alluvial Fans, relatively close spaced banded vegetation formations are discernible in the interfluve areas. Rainfall stimulates increased greenness, which progressively reduces with time since rainfall. High and more persistent greenness is associated with pockets along the drainage tracts where soil water holding capacity and replenishment volumes delivered by flow events are greatest. By capturing inflows, these areas attenuate the delivery of flows into the downgradient Fortescue Valley.
- The Fortescue Valley Flats exhibits distinct behaviours related to surface types:
    - The sparsely vegetated Stony Flats that fringe the valley have persistently low greenness, with some variability likely conferred by short lived ephemeral herbs and grasses.
    - The Calcrete surfaces also tend to have relatively low greenness, with minor variability within this unit putatively associated with microtopography and soil depth (i.e. lowest values where calcrete is shallow or outcrops). East of the Gnalka Gnoona Claypan, calcrete confines a band of Loamy Flats between the Stony Flats of the valley fringe.
    - The Loamy Flats are characterised by much higher greenness that follows a seasonal pattern linked to rainfall. Zones of high and more persistent greenness abut the Stony Flats on the valley flanks, consistent with these areas receiving and capturing runoff from the Stony Flats. They are often also proximal to the drainage termini at the base of the Alluvial Fans. Greenness typically diminishes with distance from the valley edge, suggesting attenuation of water movement into the downgradient Fortescue Valley. This pattern can be explained by high surface roughness and infiltration on the Lomay Flats landscape unit.
    - The Ponding Flats exhibit low greenness owing to the sparseness of vegetation on these surfaces. Transient waterbody formation and dissipation is evident in the imagery. High greenness can develop around the fringes of the Ponding Flats after significant rains, at the interface with the Loamy Flats. This suggests a mechanism of soil water replenishment deriving from the ponded waterbodies.

[3] Bureau of Meteorology: http://www.bom.gov.au/climate/austmaps/about-ndvi-maps.shtml

7.10 Spatial Analysis of Remote Sensing Data

A key question at the outset of the ecohydrological assessment was the potential occurrence of groundwater using vegetation in the Study Area and surrounds. As part of addressing this question, spatial analysis of remote sensing data was completed. Remote sensing methods have been found to be useful for identifying potentially groundwater dependent vegetation in the Pilbara and other arid environments (Barron et al 2014).

The analysis involved time series analysis of multispectral indices derived from high resolution (10 x 10 m pixel) imagery captured by the European Space Agency's Copernicus Sentinel-2 platform. The following indices were used:

- Normalised Difference Vegetation Index (NDVI) – a ratio based on near-infrared and red wavelengths that is a reliable indicator of chlorophyll levels (density and vigour of vegetation). NDVI values vary between -1 and +1, typically ranging between 0.1 and 0.7 for vegetation in Australia[4]. Higher values are associated with greater density and 'greenness' of the plant canopy and values decrease as plants become water stressed, diseased or die. NDVI values <0 are indicative of waterbodies.
- Normalised Difference Wetness Index (NDWI) – a ratio based on near-infrared wavelengths and shortwave infrared wavelengths. Values vary between -1 and +1, with values <-0.8 associated with bare soil, values <-0.6 associated with very sparse vegetation, and plant water stress decreasing with increasing values >0.

The period used for the remote sensing analysis was 17 May 2017 to 18 December 2017, corresponding to a period of progressively increasing drought following relatively high rainfall (114 mm) in March/April 2017. Assessment locations based on vegetation mapping data were used to define a suite of land cover classes, for which NDVI and NDWI trends were determined. Land cover classes with invariant greenness and wetness during protracted drought indicate the potential for groundwater use by vegetation, where other water sources (e.g. irrigation) can be ruled out (Barron et al. 2014). Further details are provided in the remote sensing assessment report prepared by Woodgis (Appendix Q).

[4] Bureau of Meteorology: http://www.bom.gov.au/climate/austmaps/about-ndvi-maps.shtml

8. DELINEATION OF ECOHYDROLOGICAL UNITS

8.1 Overview

The findings of the knowledge review, site inspection and remote sensing data (Section 7) underpinned the identification of ten landscape ecohydrological units (EHUs), which are summarised in Table 8.1.

The spatial distribution of these EHUs was delineated from the on-ground observations (within the 2023 AOI) augmented by interpretation of topography, geology mapping, aerial photography and Sentinel-2 remote sensing imagery (Figure 8.1). It is noted ground-truthing was not undertaken for the delineation of the EHUs over the extended 2024 AOI.

Conceptual models were developed that describe the key elements and functional aspects of each EHU, which are further described in Section 8.2 (Chichester Range Uplands), Section 8.3 (Alluvial Fans) and Section 8.4 (Fortescue Valley Flats).

Table 8.1 Summary of Landscape Ecohydrological Units in the Area of Interest (AOI)

	EHU	Summary description	Hydrological behaviour
Chichester Range Uplands	Upland Rises	Peaks and upper hillslopes; shallow or skeletal soils overlying basement rocks.	Runoff source areas – shed water to downgradient landscape units.
	Upland Valleys	Broader depressions in the Chichester Range where sediments have accumulated, facilitating runoff capture/storage and denser vegetation.	Local sink area, receiving diffuse flow from Upland Rises Surplus from overtopping delivered into Upland Drainages.
	Upland Drainages	Single thread channels with cobble beds that traverse and exit the Chichester Range. Unconfined to semiconfined by hills of basement rocks. Channel beds mostly unvegetated with regular gravel bars and scour pockets. Scattered *E. victrix* trees in deeper soil pockets fringe the channels.	Transfer zones, receive runoff from upland catchments and transmit into Alluvial Fan Drainages.
	Basaltic Tablelands	Level to very gently inclined basaltic plains. Soils mostly comprise self-mulching cracking clays supporting tussock grassland communities.	Local sink area, receiving direct rainfall or locally distributed runoff
Alluvial Fans	Alluvial Fan Washplains	Banded vegetation (mulga and Snakewood) on a gently sloping stony plain. Runoff is generated in intergrove areas and mostly captured in the adjacent downslope grove.	Local sink area receiving rainfall. Surplus from overtopping delivered into Alluvial Fan Drainages.
	Alluvial Fan Drainages	Low sinuosity channels with narrow floodplains, collectively constituting drainage tracts, which dissect the Alluvial Fan Washplains. Supports relatively dense mulga shrubland.	Transfer zones, receive runoff from Upland Drainages and transmit into the Fortescue Valley.
Fortescue Valley Flats	Valley Calcrete Plains	Expansive unit of the Fortescue Valley. Variably dissected and overprinted by alluvium, giving rise to a subtle mosaic of benches, rises and depressions. Vegetation type and density related to soil depth, which is constrained by shallow calcrete (generally within 50 cm of the surface).	Benches and rises function as runoff source areas once internal storage is exceeded, shedding water to immediately adjacent units.
	Valley Stony Flats	Stony flats in the Fortescue Valley, generally on the valley margins where slope (and hence runoff) is insufficient to support banded vegetation. Prone to accumulation of salts due to poor infiltration; only sparsely vegetated. These areas support transient but not persistent ponding.	Receive inflows from Alluvial Fan Drainages. The flat stony pavement surfaces function as runoff source areas once internal storage is exceeded, shedding water to immediately adjacent units.

	EHU	Summary description	Hydrological behaviour
	Valley Loamy Flats	Broad flats typically inset from the valley margins, where accumulated sediment and organic matter create better soil structure and high infiltration rates. Relatively deep soils (may exceed 100 cm). High surface roughness contributes to some localised surface water redistribution within the unit. These areas support dense patches of woodland and grassland vegetation; with vegetation types related to subtle changes in physical and chemical soil properties.	Predominantly sink areas that receive runoff from adjacent units (Valley Stony Flats and Calcrete Plains). Overtopping is uncommon and associated with large cyclonic rainfall events.
	Valley Ponding Flats	The lowest depressions in the Fortescue Valley where water ponds; typified by high clay content topsoil that impedes infiltration. Prone to accumulation of salts due to poor infiltration; only sparsely vegetated. These areas support persistent ponding.	Sink areas that collect rainfall and receive runoff from adjacent units (Valley Stony Flats and Calcrete Plains, and more rarely Loamy Flats).

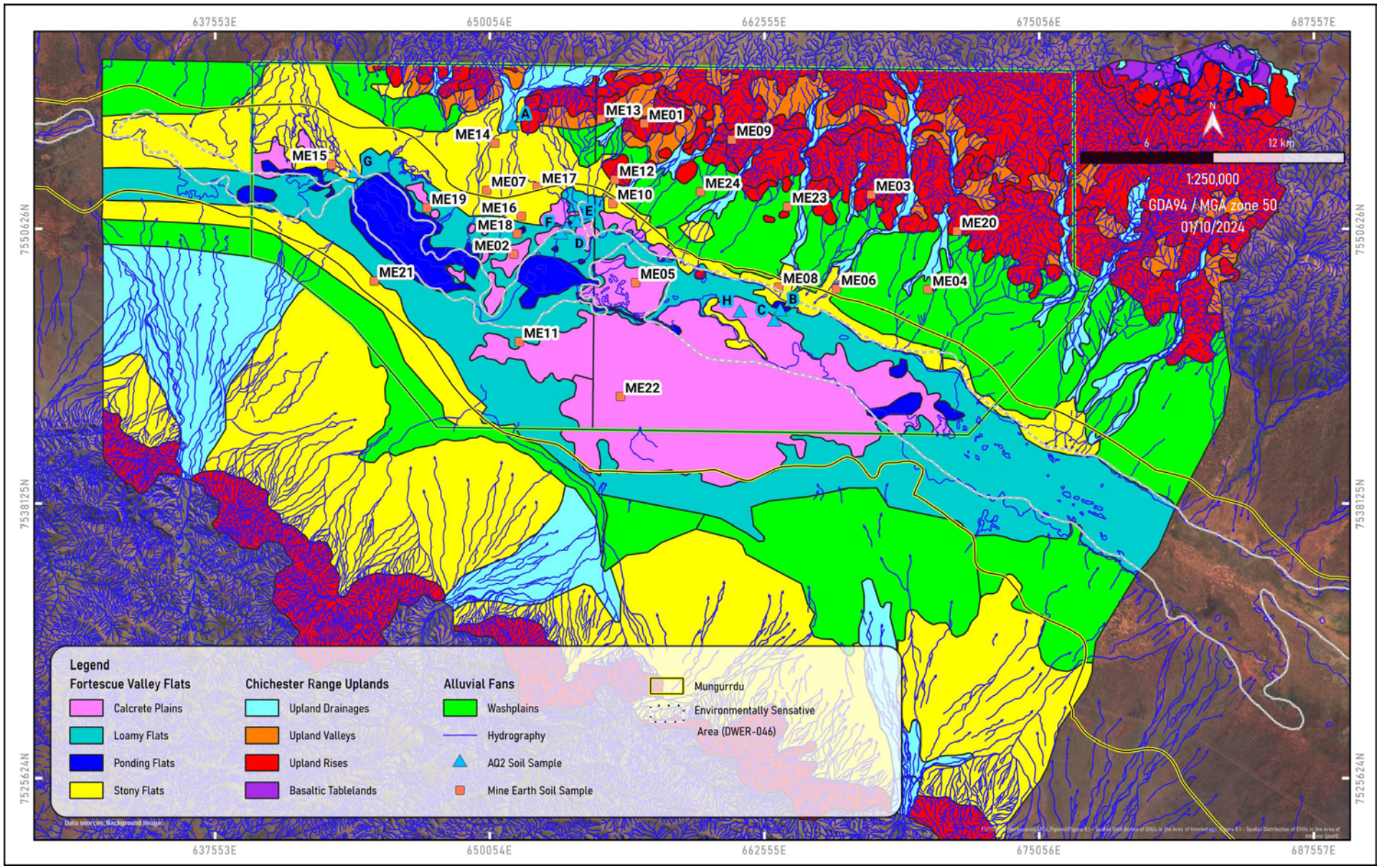


Figure 8.1 Spatial Distribution of EHUs in the Area of Interest

8.2 Chichester Range Uplands

8.2.1 Landscape Context

The uplands of the Chichester Range include the following landscape ecohydrological units:

- Upland rises.
- Upland valleys.
- Upland drainages.
- Basaltic tablelands.

The conceptual ecohydrological model for these units is schematically depicted in Figure 8.2.

8.2.2 Elements

Key elements of the Chichester Range Uplands ecohydrological units are described as follows:

- Upland rises:
  - Land surface – gently to steeply inclined rocky crests and ridges.
  - Regolith – shallow or skeletal soils with frequent bedrock exposures.
  - Groundwater – the regional groundwater system, hosted in basement rocks, is deep and inaccessible to vegetation.
  - Keystone vegetation – dominated by spinifex grasses (*Triodia* spp.), with scattered trees (*Eucalyptus leucophloia* subsp. *leucophloia* +/- *Corymbia hamersleyana*) and shrubs (*Acacia* spp.). These are generally regarded as shallow rooted, highly drought tolerant species. Higher density vegetation patches are associated with greater soil depth.
- Upland valleys:
  - Land surface – open depressions between crests and ridges, typically up to several hundred meters wide and with a flat to gently undulating base near the base of the Chichester Range.
  - Regolith – soils of variable depth and texture derived from colluvium and alluvium, often with significant gravel content.
  - Groundwater – the regional groundwater system, hosted in basement rocks, is deep and inaccessible to vegetation.
  - Keystone vegetation – mixed Acacia spp. shrubland, with sparse/patchy tussock grass (*Themeda triandra*) and scattered trees (*Eucalyptus victrix* +/- *Corymbia hamersleyana*). Higher density vegetation patches are associated with greater soil depth.
- Upland drainages:
  - Land surface – single thread, unconfined to semiconfined channels with a cobble base that dissect the Upland valleys, with indistinct floodplains. Sometimes with poorly defined flood runners infrequently activated by larger events.
  - Regolith – channels cut into the valley colluvium, alluvium. Depth of incision mediated by gravel bed and ultimately constrained by consolidated regolith materials.
  - Groundwater – the regional groundwater system is deep and inaccessible to vegetation. Some transient perching of water under the channel sediments may occur in niche locations such as clay lined scour pockets.
  - Keystone vegetation – the banks of the channels are typically lined with well-spaced (sparse) Eucalyptus victrix trees and Acacia shrubs.
- Basaltic Tablelands:
  - Land surface – level to very gently inclined basaltic plains up to 4 km in extent, commonly with gilgai microrelief.

- Regolith – the in situ formed soils are predominantly fine textured, mostly comprising self-mulching cracking clays and some deep red-brown non-cracking clay with mantles of basaltic pebbles and cobbles (up to boulders).
- Groundwater – the regional groundwater system, hosted in basement rocks, is deep and inaccessible to vegetation.
- Keystone vegetation – the basaltic tablelands support tussock grassland communities, with major taxa including *Eragrostis xerophila* (Roebourne Plains grass), *Aristida latifolia* (Feathertop threeawn) and *Astrebla pectinate* (Barley Mitchell grass), with patches of *Triodia spp.* and sparse mixed shrubs. The basaltic tablelands are associated with the Wona land system, which contains four priority listed ecological communities (DBCA, 2023) and the Priority 3 species *Glycine falcata*.

8.2.3 Processes

Key processes within and across Chichester Range Uplands ecohydrological units are described as follows:

- Upland rises:
  - Soil water replenishment/loss – infiltration of direct rainfall. High evaporation losses. Soil water storage rapidly depleted by vegetation.
  - Surface drainage - significant runoff losses. Generally short distance overland/diffuse flow into dendritic drainage networks (1st order flow lines). Rapid shedding of storage excess.
  - Groundwater recharge – minimal recharge owing to restricted infiltration/low permeability basement above the water table.
  - Vegetation water use – plants exhibit a pulse/dormancy dynamic linked to rainfall events, and are exposed to a high degree of drought stress.
- Upland valleys:
  - Soil water replenishment/loss – infiltration of direct rainfall augmented by delivered runoff. Soil water storage rapidly depleted by vegetation.
  - Surface drainage - surface accumulation and infiltration of flood flows (overland flows and channel breakouts). Excess volumes transferred to adjacent channels (Upland drainages unit).
  - Groundwater recharge - minimal recharge as water inputs are predominantly stored in the soil profile and depleted by vegetation.
  - Vegetation water use – plants exhibit a pulse/dormancy dynamic linked to soil moisture dynamics. Seasonal exposure to drought stress in the Pilbara dry season.
- Upland drainages:
  - Soil water replenishment/loss – principally associated with flow events.
  - Surface drainage – receive, aggregate and transmit rapidly delivered runoff pulses as high energy flows. Bed load movement restricts vegetation establishment within the channels. Banks rarely overtop into surrounding valley. Gravel banks and bars contribute to surface roughness in the channels.
  - Groundwater recharge – transient, focussed recharge in the channels may be associated with flow events. However, the majority of inflows are transmitted downstream.
  - Vegetation water use – the vegetation exhibits a pulse/dormancy dynamic linked to soil moisture dynamics. Exposed to seasonal drought stress in the Pilbara dry season.
- Basaltic Tablelands:
  - Soil water replenishment/loss – infiltration of direct rainfall or locally distributed runoff. In the case of cracking clays, desiccation cracks may facilitate preferred pathway infiltration via deep percolation paths.

- Surface drainage – minimal lateral redistribution of rainfall due to low surface gradients, grassy vegetation and infiltration.
- Groundwater recharge – minimal owing to low permeability of fine textured soils and vadose water uptake by vegetation.
- Vegetation water use - the vegetation exhibits a pulse/dormancy dynamic linked to soil moisture dynamics. Exposed to seasonal drought stress in the Pilbara dry season.

8.2.4 Data Gaps/Uncertainties

Data gaps and uncertainties relating to the ecohydrology of Chichester Range Uplands ecohydrological units include:

- Quantification of rainfall/runoff relationships and associated streamflow behaviour. Surface water loggers installed by AQ2 in 2018 in some of the channels are starting to provide relevant data.
- The depth and soil water holding capacity of upland soils is inferred but has not been measured to date.
- Vegetation water use dynamics as related to soil moisture status.

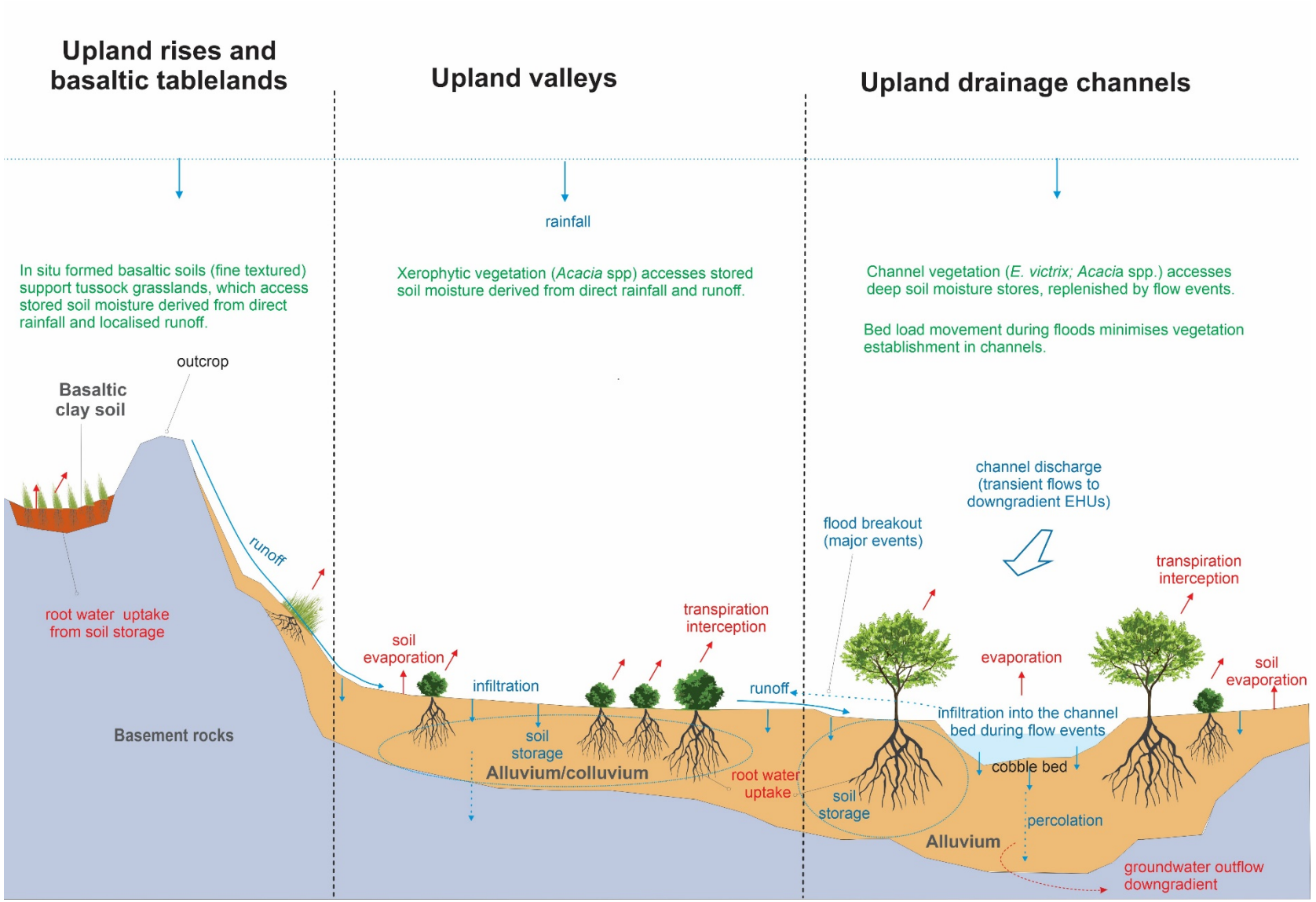


Figure 8.2 Ecohydrological Conceptualisation of the Chichester Range Uplands

8.3 Alluvial Fans

8.3.1 Landscape context

The alluvial fans connecting the foothills of the Chichester Range to the Fortescue Valley flats include the following ecohydrological units:

- Alluvial Fan Washplains.
- Alluvial Fan Drainages.

A series of alluvial fans are distributed along the southern margin of the Chichester Range, typically several kilometres in length (from apex to toe) and width. Larger fans are associated with larger drainage catchments. Each fan typically hosts one or two primary drainages.

The conceptual ecohydrological model for these units is schematically depicted in Figure 8.3.

8.3.2 Elements

Key elements of the Alluvial Fans ecohydrological units are described as follows:

- Alluvial Fan Washplains:
  - Land surface – broad, very gently inclined (slope approx. 0.5% to 0.7%) inter-drainages, where surface grade and soil type create favourable conditions for banded (groved) vegetation development. The intergroves are typified by stony pavement surfaces.
  - Regolith – the soils of the intergroves comprise a stony mantle, with a shallow fine textured A horizon and hard, gravelly subsoils. Soils of the groves included well structured, loamy surficial soils influenced by organic matter concentration. The entire surface is underlain by red-brown hardpans that restrict water percolation and deep root penetration.
  - Groundwater – the regional groundwater system, hosted in variably consolidated Tertiary sediments underlying the alluvium, is inaccessible to vegetation.
  - Keystone vegetation – the groves are dominated by mulga (*Acacia aneura* species complex). Mulga has a low tolerance of waterlogging and is vulnerable to modified hydrological regimes that promote waterlogging, such as surface water impoundment. Mulga are also sensitive to salinity and tree deaths in the species have been linked to elevated salinity caused by dust suppression using hypersaline water on haul roads (Davies and Van Etten 2004). Conversely, mulga trees are highly drought tolerant with adaptations including phyllode anatomy, anisohydric water use physiology and an ability to maintain extremely low (negative) stem water potentials (< -10 MPa) (Page 2013). Vadose moisture reservoirs above the hardpan provide for the carry-over of soil moisture used by groved vegetation across seasons and years (Cleverley et al. 2016).
  - Mulga are recognised as shallow rooted species (roots within the surface few meters) and inferred to be disconnected from groundwater throughout the alluvial fan landforms. A field investigation of mulga root system morphology on alluvial fan soil profiles north of the Fortescue Marsh, a putatively similar landscape setting approximately 100 km east of the AOI, was completed by Astron Environmental Services (Astron) in 2012 as reported in Equinox (2013). This work indicated that the vast majority, if not the entirety of the root systems, were located in the top 200 cm of the soil profile.
- Alluvial Fan Drainages:
  - Land surface – the drainage tracts are subtle, open depressions with a narrow low flow channel (up to a few metres wide) generally central within the tract.
  - Regolith – the soils of the drainage tracts are similar to the grove soils on the interfluves, but with a larger sediment component deriving from the Chichester Uplands. The hard subsoil (red-brown hardpan) sometimes outcrops in the channel beds and constitutes a barrier to channel incision.

- Groundwater – the regional groundwater system, hosted in variably consolidated tertiary sediments, is inaccessible to vegetation.
- Keystone vegetation – Mulga dominated and similar to the groves on the adjacent interfluves, but often forming wider and denser stands owing to greater inflows from upgradient (i.e. functionally mega-groves). Often include a more prominent grass understorey component. Support higher levels of plant recruitment owing to the more favourable soil moisture regime.

8.3.3 Processes

Key processes within and across Alluvial Fan ecohydrological units are described as follows:

- Alluvial Fan Washplains:
  - Soil water replenishment/loss - by direct rainfall augmented by runoff from intergrove to downgradient grove. Lateral water redistribution is principally controlled by the duration and intensity of rainfall events (Crompton and Thompson 2021). In large and intense rainfall events greater amounts of water can escape the system entirely as runoff to the Alluvial Fan drainages.
  - Surface drainage - local scale sheetflow environments. Intergrove areas between the mulga groves (i.e. bands or patches) are much less vegetated and soils have lower infiltration than in the groves. These areas tend to shed water onto the downgradient trees. Various studies of banded vegetation formations in Australia and elsewhere have shown that specific rainfall/runoff characteristics contribute to the width of groves and intergroves respectively (Dunkerley 2002; Dunkerley 2018; Crompton and Thompson 2021). On this basis, local scale water redistribution is inferred to be the primary driver of soil water replenishment for the mulga groves. However, surface flow patterns are inherently complex and spatially heterogeneous. Larger scale flow processes (i.e. involving lateral water movements across multiple groves/greater distances) may also be important for soil water replenishment and vegetation ecological water requirements.
  - Groundwater recharge - minimal recharge as water inputs to the groves are predominantly stored in the soil profile and depleted by vegetation.
  - Vegetation water use:
    - Mulga exhibit a short pulse/long dormancy growth pattern in connection with water inputs (Cleverley et al. 2016).
    - Mulga communities include a suite of annual plants that complete their life cycle seasonally.
    - The mulga groves are zones of increased biological activity including litterfall, nutrient cycling and soil biota that contribute to enhanced infiltration characteristics (Pringle et al. 1994). These zones help to facilitate the recruitment of new mulga plants, in conjunction with eventual death of old trees creating 'resource gaps' for new recruits.
- Alluvial Fan Drainages:
  - Soil water replenishment/loss - dominated by flow events, augmented by locally generated runoff from adjacent areas and rainfall.
  - Surface drainage – receive high energy flows from the Upland Drainages, with progressive energy dissipation moving from fan apex to toe. This is associated with a reduction in channel size to the point of total channel dissipation on entry to the Fortescue Valley Flats. These downstream areas include accumulations of fine sediments. Large events activate the full width of the drainage tracts.
  - Groundwater recharge - minimal recharge as water inputs to the groves are predominantly stored in the soil profile and depleted by vegetation.
  - Vegetation water use – functionally similar to the Alluvial Fan Washplain groves.

8.3.4 Data Gaps/Uncertainties

Data gaps and uncertainties relating to the ecohydrology of Alluvial Fan ecohydrological units include:

- The relative importance of local scale (i.e. the intergrove immediately upslope) versus broader scale overland flow processes for soil water replenishment, and methods for evaluating this on a case-by-case basis. This determines the vulnerability of these vegetation formations to disrupted surface water flows associated with linear infrastructure and other types of disturbance. If local scale processes are overriding, then the impacts of disrupted hydrology will be spatially constrained.
- Plant recruitment and attrition dynamics in mulga vegetation communities.
- Tolerance thresholds of mulga trees to the combined effects of altered surface water flow regimes, climate change and other impacts such as cattle grazing.

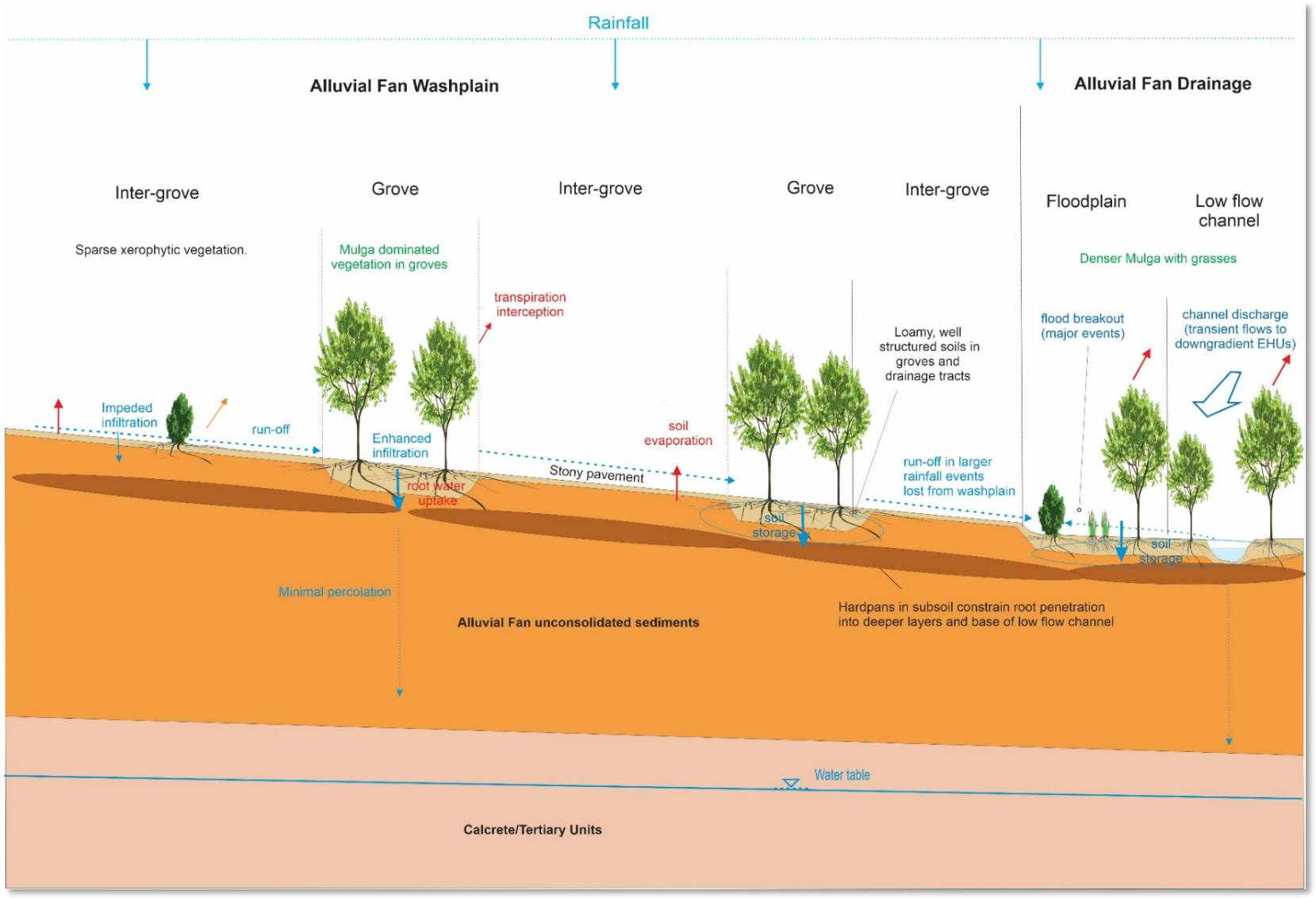


Figure 8.3 Ecohydrological Conceptualisation of the Alluvial Fans

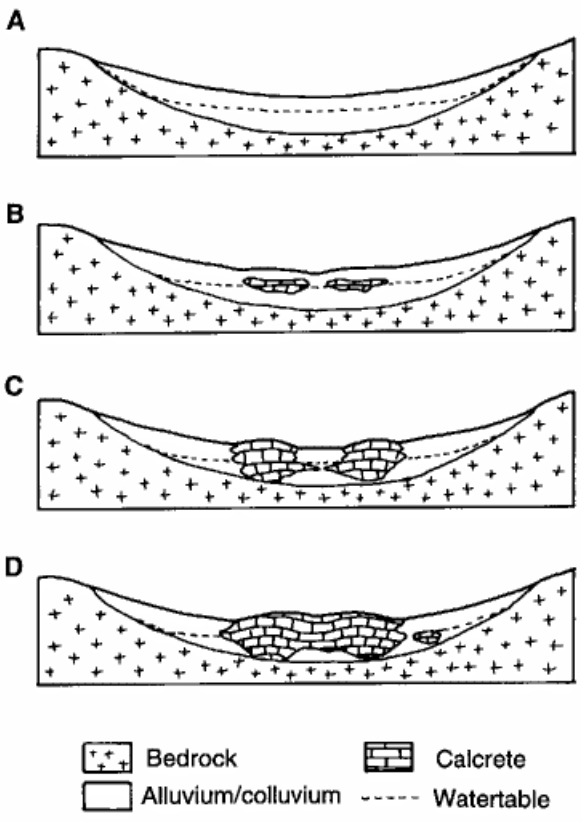
8.4 Fortescue Valley Flats

8.4.1 Landscape Context

The expansive flats of the Fortescue Valley include the following landscape ecohydrological units:

- Stony Flats.
- Calcrete Plains.
- Loamy Flats.
- Ponding Flats.

These units form a heterogeneous mosaic across the valley. The present landscape is strongly influenced by thick calcrete sheeting formed across the breadth of the valley sediments, in association with the valley groundwater system. This is a common regolith unit in the paleovalleys of central and western Australia (Chen et al. 2002). A conceptual model of the landscape evolution of valley calcretes is shown in Figure 8.4. In zones of groundwater fluctuation, calcrete is often further hardened by secondary silicification.



A) Shallow groundwater system in a broad drainage channel

B) Initial carbonate precipitation

C) Growth of pods and domes

D) Maturation of calcrete and surface reworking

Figure 8.4 Stages in the development of valley calcrete in western and central Australia (reproduced from Mann and Horwitz 1979)

The variably undulating calcrete surface has largely been overprinted with outwash materials from the alluvial fans of the Chichester Range to the north and Hamersley range to the south; however, the calcrete frequently outcrops in places as low rises.

The Stony Flats are principally an extension of the Alluvial Fan Washplains, which transition into this unit where slope decreases to circa ≤0.1% on the outer margins of the valley.

The Loamy Flats have developed in areas that have developed deeper soils, with a positive feedback of water capture and biological productivity leading to improved soil structure and vertical drainage (i.e. functional 'mega-groves').

The Ponding Flats occur in local depressions in the aforementioned units (e.g. in discontinuous channel pockets or upgradient of calcrete barriers) and in the largest and lowest depressions in the central valley, which comprise the Gnalka Gnoona and Koodjeepindarranna claypans.

A shallow groundwater system is hosted in the calcrete layer of the valley regolith. The groundwater is brackish to saline, with salinity increasing towards the valley centre and with depth. Beneath a weathered and soften veneer, the calcrete is massive and inferred to be impenetrable to plant roots as has been observed in other locations in inland Western Australia (e.g. Pracilio et al. 2006; Carter and White 2009).

The conceptual ecohydrological model for these units is schematically depicted in Figure 8.5.

8.4.2 Elements

Key elements of the Fortescue Valley Flats ecohydrological units are described as follows:

- Stony Flats:
  - Land surface – typified by flat, stony pavement surfaces with sparse vegetation. Commonly display subtle microtopography with small depressions collecting fine sediment and functioning as rainfall sumps. Often with a veneer of fine sediment near the Alluvial Fan drainage termini.
  - Regolith – Poorly structured, low permeability and salt affected soils. Subsoils comprise red-brown hardpans similar to the Alluvial Fan soils, which overlie calcrete at depths of up to several meters. High sulfur content possibly deriving from the concentration of aeolian dust washed in from the Alluvial Fans over geological time.
  - Groundwater – shallow and brackish; hosted in the calcrete layer that acts as a barrier to roots.
  - Keystone vegetation – the vegetation is sparse and comprises hardy, drought and salt tolerant species such as *Acacia xiphophylla* and *A. synchronicia*.
- Calcrete Plains:
  - Land surface – weathered calcrete either outcropping or blanketed in a shallow (<50 cm) soil layer. Can occur as flat benches or low rises throughout the valley.
  - Regolith – loamy, moderately structured soil (where present) often with a high percentage of calcrete nodules, overlying weathered calcrete that becomes progressively massive and harder at depth. Variable infiltration rates depending on local scale factors (depth of soil, gravel content etc).
  - Groundwater – shallow and brackish; hosted in the calcrete layer that acts as a barrier to roots.
  - Keystone vegetation – predominantly spinifex grasses (*Triodia* spp.) with scattered trees (*Eucalyptus victrix*) and shrubs (*Acacia* spp.). Areas of deeper soil support tall *Acacia* shrublands.
- Loamy Flats:
  - Land surface – complex microtopography and high surface roughness conferred by variable clay content and shrink/swell behaviour.

- Regolith – well-structured earthy soils near the surface. High plant available water storage capacity. The subsoil comprises harder, poorly structured and lower permeability clays, which in turn overlie calcrete.
- Groundwater – shallow and brackish; hosted in the calcrete layer that acts as a barrier to roots.
- Keystone vegetation – the keystone species is *Eucalyptus victrix*, with *Acacia distans* also prominent. In more waterlogging prone areas *Acacia stenophylla* and *Duma florulenta* (lignum) are notable components of the vegetation community. Tussock grasslands (*Eriachne* spp.) occur in patches on soils with higher clay content that receive runoff from adjacent units with impeded infiltration.

- Ponding Flats:
  - Land surface – broad, flat based depressions with clayey surfaces.
  - Regolith – dense, low permeability clay of variable depth ultimately overlying calcrete.
  - Groundwater – shallow and brackish; hosted in the calcrete layer that acts as a barrier to roots.
  - Keystone vegetation – mostly bare of vegetation; notable species with a scattered occurrence include *Bergia perennis* subsp. *obtusifolia*, *Tecticornia verrucosa* and mixed tussock grasses mainly of *Eriachne benthamii* and *Sporobolus mitchellii*. These species are adapted to periodic inundation, waterlogging and salinity punctuated by droughts.
  - Waterbodies – the Ponding Flats support persistent, shallow waterbodies that support an ephemeral aquatic ecosystem and waterbirds including migratory species listed under the EPBC Act.

8.4.3 Processes

Key processes within and across Fortescue Valley Flats ecohydrological units are described as follows:

- Stony Flats:
  - Soil water replenishment/loss – direct rainfall and inflows from the dissipating Alluvial Fan drainages.
  - Surface drainage – poorly drained owing to flatness and impeded infiltration. The infiltration contrast with the adjacent Loamy Flats can induce lateral transport of water away from the Stony Flats during high intensity rainfall events.
  - Groundwater recharge – minimal owing to impeded percolation.
  - Vegetation water use – the sparse vegetation is inferred to have shallow, laterally expansive root systems configured to exploit rainfall captured in the surface layer.
- Calcrete Plains:
  - Soil water replenishment/loss – soil water is replenished by direct rainfall. Some localised (internal) redistribution of water may occur depending on microtopography.
  - Surface drainage – where surface storage is exceeded, the rises and outcrops shed water to fringes of adjacent units. On flatter surfaces, lateral transport of water to adjacent areas may occur during intense rainfall events.
  - Groundwater recharge – areas where water accumulates (e.g. in soil covered depressions) are likely to modestly contribute recharge to the groundwater system. The majority of water inputs are lost to evapotranspiration, with some leakage into underlying layers.
  - Vegetation water use – the majority of water inputs are lost to evapotranspiration, with some leakage into underlying layers.
- Loamy Flats:
  - Soil replenishment/loss – soil water is replenished by direct rainfall and augmented by inflows from adjacent units. High infiltration rates are facilitated by high surface roughness, cracks and macropores. Areas abutting Stony Flats and Calcrete Plains units receive inflows caused by the surface infiltration contrast.

- Surface drainage – principally sink area that trap and retain water. Some localised (internal) redistribution of water may occur depending on microtopography.
- Groundwater recharge - the majority of water inputs are lost to evapotranspiration, with infrequent leakage into underlying layers when soil water storage is exceeded.
- Keystone vegetation – the woodlands dominated by *Eucalyptus victrix* progressively deplete soil water until this is replenished by subsequent rainfall events. Water balance modelling (refer Section 9.7) suggest that the woodlands are in dynamic equilibrium with surface water inputs, with tree density/leaf area index adjustment preventing prolonged exposure to severe drought stress. Areas receiving higher runoff volumes (e.g. in local depression and on the fringes of the Stony Flats and Calcrete Plains) support denser, grassy understoreys with more persistent NDVI greenness.

- Ponding Flats:
  - Soil replenishment/loss – impeded infiltration results in prolonged water ponding, with high rates of evaporation and some limited percolation into deeper layers.
  - Surface drainage – depressions collect and hold water.
  - Groundwater recharge – infiltration and percolation to the groundwater system is impeded, however these processes operate sufficiently to flush salts in the deeper profile during prolonged ponding events.
  - Vegetation water use – plants exhibits a pulse dynamic linked to replenishment events, and are exposed to a high degree of drought stress exacerbated by soil salinity. Special adaptations are required for plants to survive in this environment.
  - Waterbodies - Shallow ponding is caused by direct rainfall augmented by local runoff and catchment runoff in larger rainfall events. The persistence of waterbodies is variable but rarely extends through the annual dry season (Sept-Nov). Ponded water is initially fresh but becomes progressively more saline owing to evapoconcentration of salts.

8.4.4 Data Gaps/Uncertainties

Data gaps and uncertainties relating to the ecohydrology of the Fortescue Valley Flats ecohydrological units include:

- Quantification of surface storage and rainfall/runoff and valley ponding relationships.
- Tolerance thresholds of keystone species to salinity, waterlogging and inundation.
- Confirmation of vegetation rooting depth.

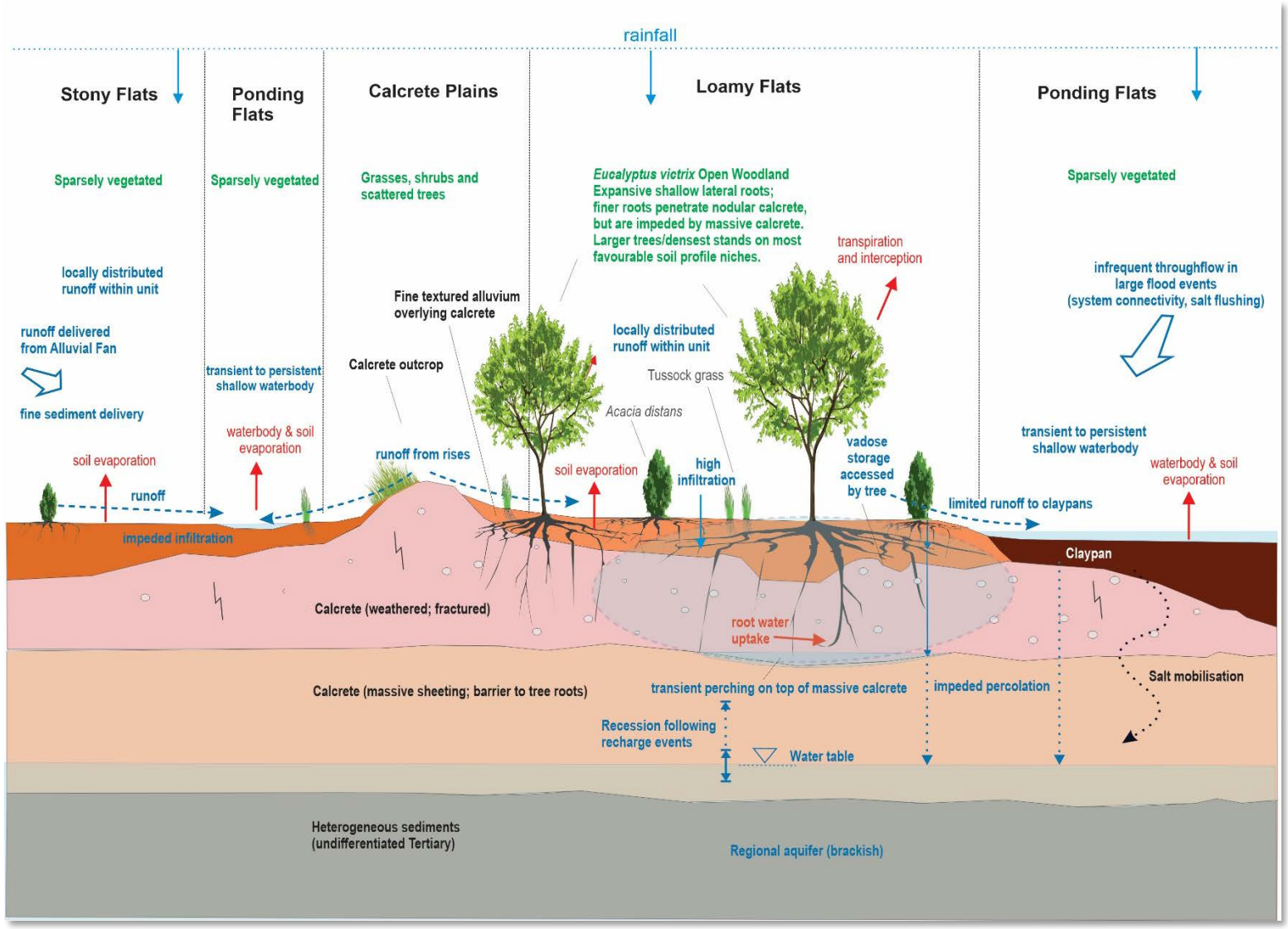


Figure 8.5 Ecohydrological Conceptualisation of the Fortescue Valley Flats

9. ASSESSMENT OF GROUNDWATER DEPENDENT VEGETATION

9.1 Assessment Approach

As outlined in the following sections of this report, potential groundwater dependence of vegetation has been evaluated using several assessment tools outlined in the Australian groundwater-dependent ecosystems (GDEs) toolbox (Richardson et al. 2011). These tools are described as follows:

- Tool 1: Landscape mapping - Locating and identifying ecosystems that are potentially groundwater dependent based on several biophysical parameters such as depth to water table, soils and vegetation type. Assessing primary productivity, water relations and/or condition of vegetation communities using remotely sensed images (i.e. time series Normalised Difference Vegetation Index) to infer use of groundwater.
- Tool 2: Conceptual modelling - Documentation of a conceptual understanding of the location of GDEs and interaction between ecosystems and groundwater; as informed by observations of soils/regolith, vegetation, groundwater and surface water features.
- Tool 3: Pre-dawn leaf water potentials - Identification of groundwater uptake by vegetation, or components of vegetation assemblages, on the basis of pre-dawn measurements of leaf water potential.
- Tool 5: Plant water use modelling - Identification of sources and volumes by using mathematical simulations of water used for plant transpiration/plant function.
- Tool 7: Plant groundwater use estimation - Measures of leaf area index or stand basal area and climatic data are used to estimate groundwater discharge from terrestrial ecosystems that have access to groundwater.
- Tool 8: Vegetation water balance - Use of water balance measurements and/or calculations to assess whether and to what extent plant water use is dependent on groundwater uptake.
- Tool 10: Evaluation of groundwater-surface water interactions - Analysis of the hydraulics of groundwater – surface water interactions. The processes by which groundwater discharges into a surface water system provides insight into the nature of groundwater dependency in wetlands, baseflow river ecosystems and in the marine environment.

Background concepts relating to groundwater dependent vegetation are presented in Appendix L.

9.2 Ecohydrological Conceptual and Numerical Models

Conceptual modelling is the process of describing a system (or study domain) of interest, identifying and characterising key elements within the system and describing relationships/linking processes between these elements. The purpose of a conceptual model is to improve system understanding and help inform planning and management decisions. In addition to providing qualitative insights into system behaviour, conceptual ecohydrological models also provide a framework for the development of mechanistic or stochastic models for more detailed investigation of specific aspects of system behaviour under past and future conditions (e.g. predictive modelling).

Ecohydrological models are fundamentally based on landscape units and water balance concepts. Natural systems are highly complex and therefore ecohydrological conceptual models necessarily include simplifying assumptions.

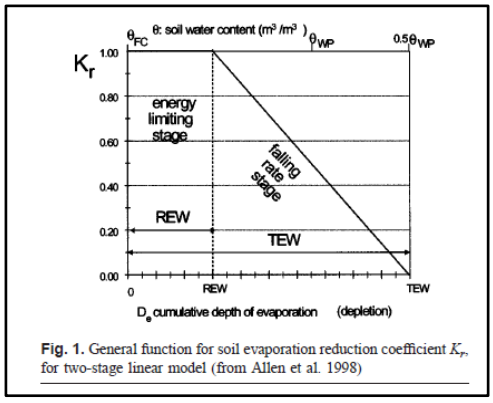
Following the data collation phase, an ecohydrological conceptual model of *E. victrix* woodland communities fringing the claypans of the lower Fortescue Valley was developed. *E. victrix* is a keystone species in the claypan environs, providing important structural habitat and being the major contributor to leaf area index and hence vegetation ecological water requirements. *E. victrix* is known to have an expansive, dimorphic root system and is a facultative groundwater using species in some Pilbara settings.

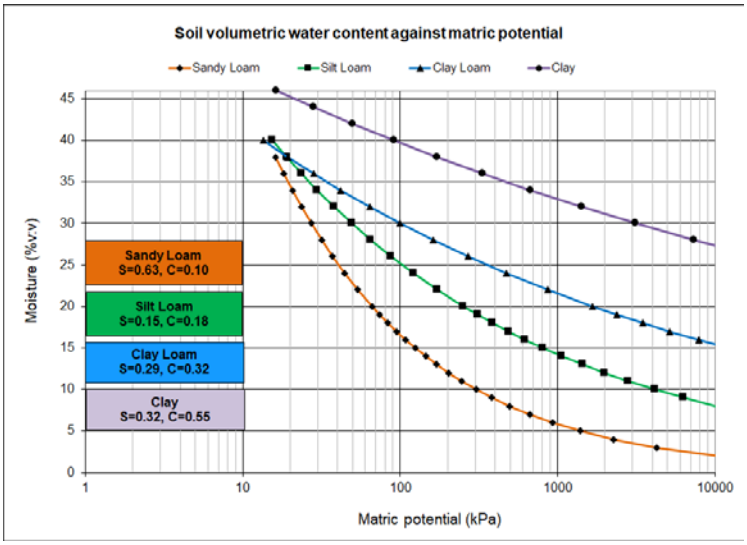
Development of the conceptual ecohydrological model involved:

- Characterisation of the key elements of the *E. victrix* communities:
  - Regolith depth, composition, and water storage properties.
  - Underlying groundwater system and groundwater quality.
  - Surface water features classified as ephemeral drainage lines, other foci and/or or waterbodies.
  - Vegetation type, structure, resilience and adaptive capacity traits, vulnerability traits (where known or able to be inferred).
- Characterisation of key processes associated with the *E. victrix* communities:
  - Groundwater regime (recharge and discharge processes, operating depth range and rate of change).
  - Surface water regime (timing, frequency, duration, magnitude and rate of change). Flow type categorised as channelised or sheet flow. Hydroperiod of waterbodies.
  - Potential water sources and ecological water requirements.
  - Level of connectivity with adjacent landscape units.

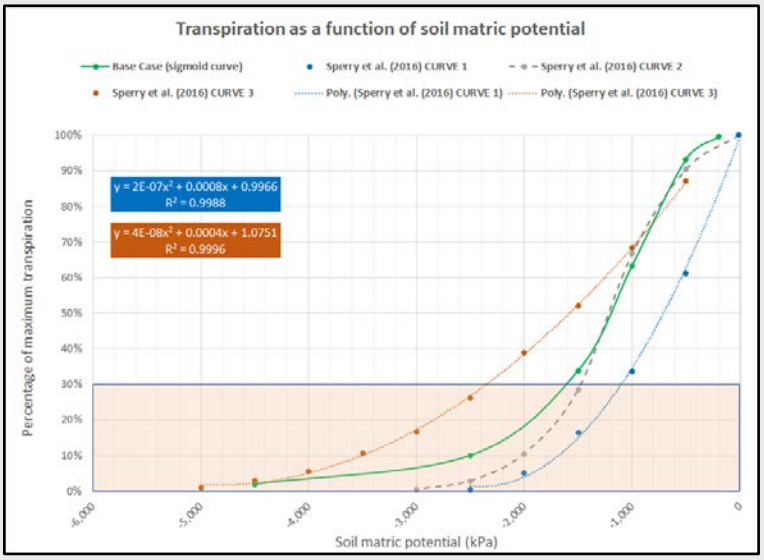
The conceptual ecohydrological model was subsequently used to formulate an ecohydrological water balance model (EWB), to enable further evaluation of *E. victrix* woodland water requirements. The EWB is a 1D vertical 'bucket type' model (i.e. no lateral water inputs or outputs) with a daily time step. A schematic depiction of the EWB model is provided in Figure 9.1, which includes base case parameters for canopy cover, stand basal area, soil profile depth and groundwater depth. The various model inputs and outputs are deterministic relationships coded in MS Excel, as summarised in Table 9.1. Note that no groundwater uptake by trees is assumed; rather the EWB provides a basis for evaluating whether rainfall inputs alone are sufficient to support the woodland trees.

Table 9.1 Components of the Ecohydrological Water Balance Model (EWB)

Water flux (input/output)	Description	
Rainfall and Potential Evapotranspiration (ETo)	Daily rainfall and ETo (FAO56) data obtained from SILO (Jeffrey et al. 2001) at location -22.10 degrees south and 118.50 degrees east (Mulga East area). Three five-year time periods were selected to be representative of average (1962-1966), dry (1949-1953) and wet (1996-2000) conditions.	
Effective rainfall	Intercepted rainfall (daily basis) calculated as per Tree life form equation of Magliano et al. (2022) for rainfall events >0.5mm; applied to nominally 25% of the model domain based on canopy cover estimates. Interception = 0.158*Rainfall+0.349	
Surface soil evaporation	Bare soil evaporation (Soil E) calculated using a multiplication factor for ETo as per the two-stage model of Allen et al. (2005) as adapted from Allen et al. (1998) and with modifier "m" for high evaporation environments as per Torres and Calera (2010) ("m" = 0.15). Soil E calculation is applicable to the full model domain. Stage 1 immediately follows precipitation events and is characterised by freely available water at or near the soil surface; evaporation is only limited by weather conditions and the amount of energy available to vaporise soil moisture Stage 1 ends when readily evaporable water (REW) is lost after cumulative evaporation of a certain amount of water, respectively to soil parameters and weather conditions. In Stage 2, evaporation is restricted by water availability because the limited hydraulic transport of soil moisture to the surface does not fully satisfy the moisture evaporative demand. Stage 2 ends with the depletion of the total evaporable water from the soil (TEW).	 Fig. 1. General function for soil evaporation reduction coefficient K_r, for two-stage linear model (from Allen et al. 1998)

Water flux (input/output)	Description
	Soil parameters (texture class; REW; TEW) derived from Allen et al. (2005) Table 1. Zc (depth of the drying layer) set as 150 mm as recommended by Allen et al. (1998). Adjustment to maximum TEW applied when ETo <5mm/day as per Allen et al. (2005). Note that small inconsistencies may arise in the daily determination of De (cumulative depth of evaporation) owing to the finite time step calculation method. As the overall error is small, a correction approach such as the 4th order Runge-Kutta method[5] (Butcher 1996; Tugwell-Wootton et al. 2020) was not applied for simplicity of computations.
Inflow to alluvium occupied by tree roots	Any rainfall that does not evaporate at the surface (daily basis) is assumed to replenish the zone of alluvium occupied by tree roots. Soil moisture content at field capacity (%v:v) determined by soil texture class as per the formulas of Saxton and Rawls (2006). Sensitivity analysis includes four soil types (Sandy Loam; Silt Loam; Clay Loam; Clay) where Clay Loam is the Base Case.  Soil moisture content at which root water uptake by *E. victrix* ceases ('Wilting Point'; %v:v) estimated from soil water retention curves (as above) where soil matric potential nominally equals -5 MPa. Plant available water (PAW) calculated as Soil Depth (mm) x (Field capacity – Wilting Point).

[5] calculates the evaporation at multiple points within the time step.

Water flux (input/output)	Description
Root water uptake and transpiration	Tree roots are assumed to occupy the full domain (i.e. root radius is about 2.5 x canopy radius). Transpiration (T) calculated using a multiplication factor for maximum Transpiration (Tmax); where Tmax is determined from stand basal area (SBA) as per the 'upper bound' of Figure 1.2 in Appendix L (i.e. where SBA =5 m^2/ha, Tmax = 160 mm/year or 0.44 mm/day). The multiplication factor is determined from fundamental relationships between T and soil matric potential as described by Sperry et al. (2016) and Carminati and Javaux (2020) (refer Appendix R). The Base Case is a plausible sigmoid function for *E. victrix* where 50% of Tmax corresponds with soil matric potential = -1.2 MPa. 
	The model does not include any understorey plants; but the application of the soil evaporation algorithm to the full model domain leads to an overestimation of Soil E, because shading by trees is not accounted for in the energy balance. This 'overestimate' constitutes a proxy for modest understorey contribution to overall evapotranspiration (e.g. such as that associated with low density shrubs and grasses that becomes inactive in dry conditions).
Groundwater recharge	The groundwater is assumed to be separated from the alluvium occupied by tree roots by a layer of massive calcrete, which restricts root penetration but does not restrict deep drainage. The depth to groundwater (>4 mbgl) is inferred from Mulga Downs bore monitoring data (refer Section 3.4). If the volumetric storage capacity of the alluvium occupied by tree roots is exceeded (daily basis) then all excess water is assumed to percolate to the groundwater system (i.e. the unsaturated calcrete layer effectively has no storage capacity) and become unavailable to trees.

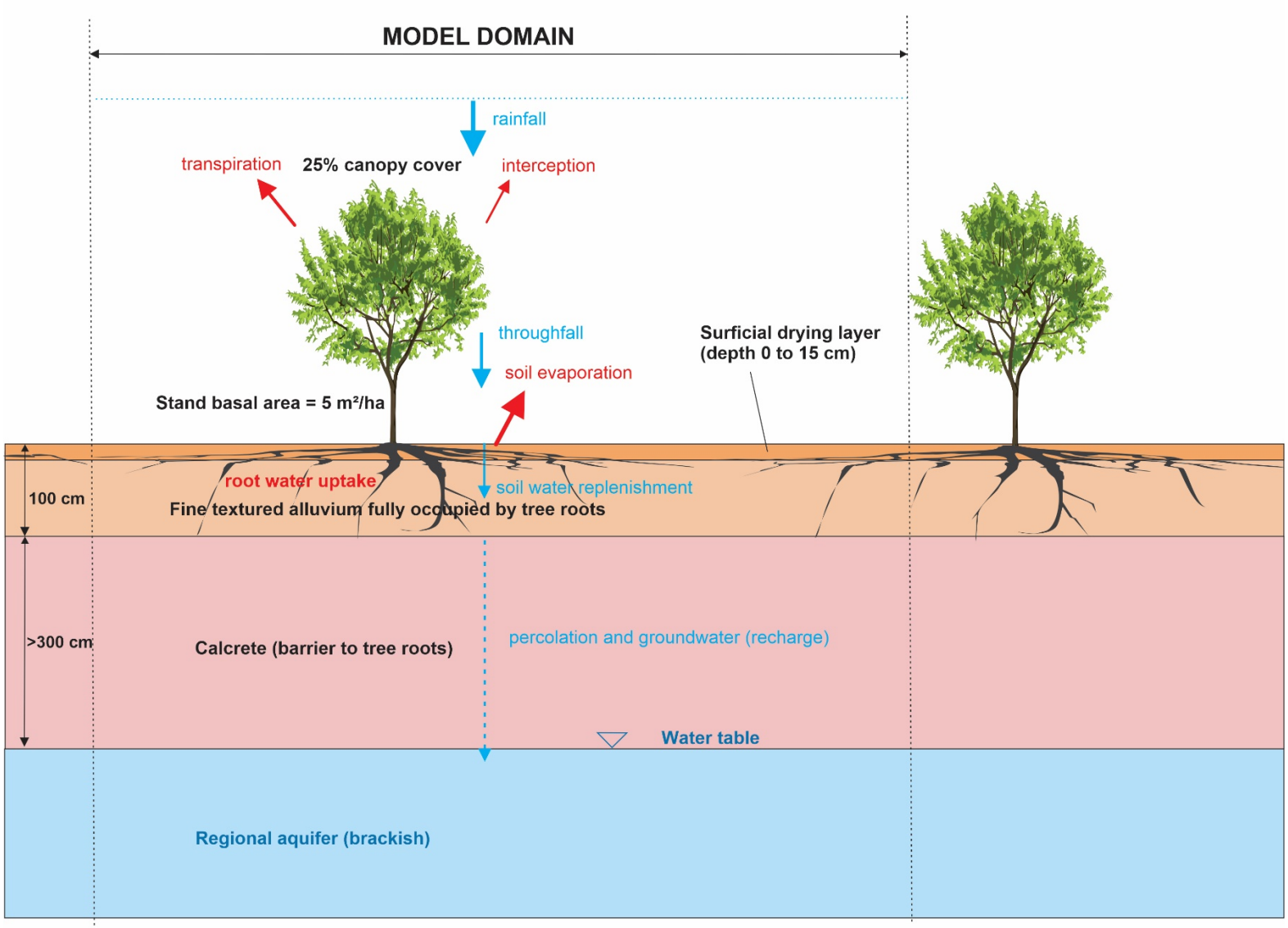


Figure 9.1 Schematic outline of ecohydrological water balance model for *E. victrix* vegetation communities in the lower Fortescue Valley

9.3 Soil and Landforms in the Fortescue Valley

9.3.1 Physical Characteristics of the Valley Alluvium

Backhoe pits in the Fortescue Valley completed by Mine Earth (2021) provide an indication of soil properties corresponding with *E. victrix* woodland vegetation (Table 9.2). In general terms, the soils are fine textured with clay content progressively increasing with depth. The upper profile has very little gravel. The subsoils are typically alkaline and variably saline. Weathered calcrete is commonly encountered at depths of 50 to 100 cm (e.g. pits ME05, ME11 and ME22). Where shallow calcrete was not encountered within the pits, the subsoil comprises massive (poorly structured) low permeability clay (e.g. pit ME19). It is likely that calcrete underlies the low permeability clay, as is evident at pit ME19 from the bore logs for nearby monitoring bores MDPZ7468A, B and C. Soil pit photographs are provided in Figure 9.2; for soil pit locations refer to Figure 7.5.

The most saline soils documented by Mine Earth (2021) occurred in a non-vegetated stony plain depression north of the Gnalka Gnoona Claypan (ME16 and ME18; saturated paste EC 4.5 to 9.1 dS/m); located near the base of an alluvial fan originating from the Chichester Range. These results are indicative of low permeability clay at relatively shallow depth causing water ponding and evaporative concentration of salts. Where more permeable soil profiles are underlain by calcrete, it appears that flushing processes are more effective in preventing salt accumulation.

The PSD results for the five grab samples collected by AQ2 from drilling sump pits in the Fortescue Valley are summarised in Table 9.3 (for sample locations refer to Figure 7.5).

The PSD of the alluvium is an important metric influencing soil hydraulic properties. In particular, the PSD controls the matric-pressure / moisture-retention relationship that affects tree-water uptake from the vadose zone. In combination with soil profile depth, PSD information can be used to estimate soil water storage capacity including the plant available water (PAW) component of this storage.

All samples except AFMB01 were generally fine grained with over 60% of these samples comprising silt and clay. In AFMB01 approximately 60% of the sample is sand-sized or coarser. These results are broadly consistent with the Mine Earth (2021) findings; noting that different laboratory methodologies are likely to have contributed to putative differences in silt and clay fractions (AQ2 samples higher silt and lower clay content). It should be noted that photographs from the excavations where the samples were collected show significant calcrete deposits interbedded within the alluvial sequence. In places, these have weathered to clay and were included in the collected samples (contributing to the clay fraction). However, where the calcrete was massive, it was not included in the sample, nor would the PSD method of analysis be appropriate to estimate unsaturated hydraulic properties for massive calcrete.

As previously mentioned, Pinder et al. (2017) also reported the following PSD results from their surficial sampling sites (0-10 cm layer) at the Gnalka Gnoona and Koodjeepindarranna Claypans:

- Gnalka Gnoona:
  - Site FV14A: Clay = 34.5%; Silt = 15.5%; Sand = 50.0%
  - Site FV19A: Clay = 40.5%; Silt = 13.5%; Sand = 46.0%
- Koodjeepindarranna:
  - Site FV17A: Clay = 34.4%; Silt = 18.8%; Sand = 46.8%
  - Site FV18A: Clay = 39.0%; Silt = 22.5%; Sand = 38.5%

These samples exhibited relatively high clay content compared with the aforementioned AQ2 and Mine Earth (2021) PSD measurements, reflecting their location in the claypan basins proper. The high clay content near the surface of the claypans contributes to restricted infiltration and protracted ponding following large rainfall events.

Table 9.2 Key characteristics of soils in the Fortescue Valley environs

Soil Pit Ref.	Soil profile information (as reported by Mine Earth 2021)
ME05	0-50 cm: Predominantly single grained soil (Sandy Clay Loam) with approximately 60% calcareous nodules 2 to 10 mm in size. Plant root abundance classified as 'abundant'. 50-100 cm: Calcareous nodules 2 to 30 mm in size in a calcareous, weakly consolidated single grained matrix. Highly alkaline and saline.
ME11	0-50 cm: Well-structured soil (Sandy Clay) with polyhedral aggregates of moderate strength, up to 70 mm in size. Approximately 20% sub-angular to subrounded coarse fragments, 2 to 30 mm in size. Plant root abundance described as 'minor'. PSD at 0-5cm depth: Clay = 17.5%; Silt = 15.6%; Sand = 66.9% PSD at 40-50cm depth: Clay = 28.1%; Silt = 15.0%; Sand = 56.9% 50-110 cm: Approximately 75% calcareous nodules of, 2 to 70 mm size within a single-grained soil matrix. Alkaline and slightly saline. 110-240 cm: Single-grained, friable weakly consolidated calcareous soil.
ME19	0-40 cm: Well-structured soil (Sandy Clay) with polyhedral aggregates of moderate strength, 10 to 50 mm in size. Approximately 20 to 30% angular to subrounded coarse fragments, 2 to 30 mm in size. Plant root abundance described as 'abundant'. PSD at 0-5cm depth: Clay = 31.4%; Silt = 17.7%; Sand = 51.0% 40-90 cm: Well-structured soil (Medium-Heavy Clay) with polyhedral aggregates of moderate strength, 10 to 50 mm. Approximately 5 to 10% ironstone nodules. Plant root abundance described as 'abundant'. Neutral pH and moderately saline. PSD at 40-50cm depth: Clay = 59.8%; Silt = 15.7%; Sand = 24.5% 90-110 cm: Massive soil with 5 to 10% ironstone nodules.
ME22	0-50 cm: Well-structured soil (Silty Clay Loam grading to Silty Clay) with polyhedral aggregates of moderate strength, up to 100 mm in size. Approximately 10% angular to sub-rounded coarse fragments, 2 to 10 mm in size. Plant root abundance described as 'moderate'. PSD at 0-5cm depth: Clay = 33.2%; Silt = 27.6%; Sand = 39.2% PSD at 40-50cm depth: Clay = 46.0%; Silt = 24.0%; Sand = 30.0% 50-130 cm: Approximately 70% ironstone and calcareous nodules, 5 to 30 mm in size, in a single grained calcareous matrix. Slightly alkaline and slightly saline.

Table 9.3 Summary of Particle Size Distribution (PSD) from AQ2 samples

Sample / Site	% Passing				Total Fines
	Clay	Silt	Sand	Gravel	
MDPZ7451	13%	55%	31%	1%	99%
MDPZ7449	14%	62%	23%	1%	99%
MDPZ7459	8%	33%	52%	7%	93%
MDPZ7449	11%	53%	33%	2%	98%
MDPZ7452	16%	69%	15%	1%	99%

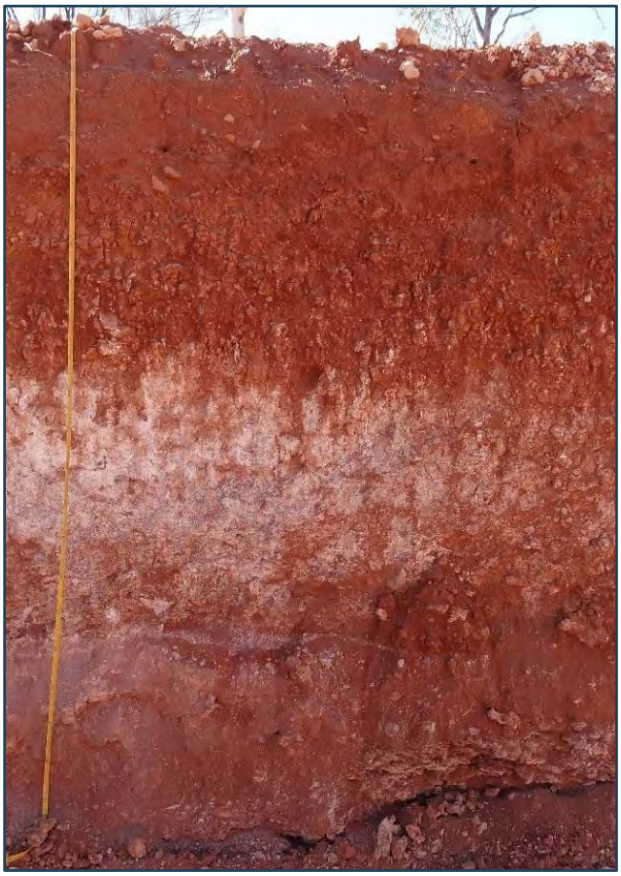
Total fines = proportion of total sample mass that is clay, silt and sand
Sample locations shown in Figure 7.5



Site ME05



Site ME19



Site ME11



Site ME22

Figure 9.2 Examples of soil profiles in the Fortescue Valley (reproduced from Mine Earth 2021)

9.3.2 Unsaturated Zone Hydraulic Properties

Unsaturated hydraulic properties of the alluvium have been estimated from the PSD analysis using a methodology developed by the USDA (Saxton and Rawls 2006); the results are summarised in Table 9.4 and discussed as follows:

- The specific yield of the alluvium is 13% and 36% for the fine- and coarse-grained alluvium respectively. The specific yield represents the water that will be released during gravity-drainage from a fully saturated state and thus, only affects zones that are subject to groundwater inundation (for example during water level rises after recharge). The lower specific yield of the fine-grained alluvium means that there will be more moisture content in the vadose zone after gravity drainage (i.e. for unsaturated conditions, there will be more plant available water in the fine-grained alluvium).
- After gravity drainage, when the alluvium is partially saturated and matric pressures become negative, then:
    - At -30 kPa (the matric pressure below which gravity drainage ceases) the volumetric moisture content is 24% and 5% for the fine-grained and coarse-grained alluvium respectively.
    - At -5,000 kPa (the approximate matric pressure below which transpiration by *Eucalyptus victrix* becomes negligible; refer Section 3.6.5) the volumetric moisture content is 4% and <1% for the fine-grained and coarse-grained alluvium respectively.
    - These values correspond with maximum plant available water (PAW) storage of circa 19% (i.e. 190 mm/m vertical depth) and 5% (i.e. 50 mm/m vertical depth) for the fine-grained and coarse-grained alluvium respectively.
- The saturated horizontal hydraulic conductivity is around <0.2 m/d for the fine-grained alluvium and 4 m/d for the coarse-grained alluvium. During inundation events, once the alluvium is saturated, relatively high rates of infiltration will occur. Typically, vertical hydraulic conductivity is in the order of 1:10 of the horizontal hydraulic conductivity (due to stratification within the alluvium). Thus, when saturated, infiltration is likely to occur at around 0.02 m/d to 0.50 m/d. Based on the predominance of fine-grained material in the samples collected and clay-nature of the soils on the surface of the claypans, it is likely that infiltration will be at the lower end of this range (0.02 m/d).
- Percolation through the vadose zone will decline very quickly once the alluvium starts to dry and moisture content and matric pressure decrease; at -30 kPa (the matric pressure at which gravity drainage will stop), the hydraulic conductivity is 1×10^{-3} to 1×10^{-5} m/d. At a matric pressure of -200 kPa, the hydraulic conductivity ranges between 1×10^{-5} to 1×10^{-8} m/d.
- The estimated capillary fringe ranges between 82 cm and 138 cm for the fine-grained alluvium. However, even though groundwater levels are relatively shallow under the clay plans, the very low unsaturated hydraulic conductivity will limit the volume of water that can actually rise from the capillary fringe into the vadose zone. It is estimated that there will be effectively no capillary rise where the alluvium is coarser.

9.3.3 Calcrete Barrier

During field reconnaissance activities, opportunistic observations of the soil profile (totalling approximately 1.5 km of exposed soil sections) were made at several bore sump pits in the vicinity of the Gnalka Gnoona and Koodjeepindarranna Claypans. The calcrete layer underlying the clayey alluvial soil was observed to become increasingly massive with depth below the overlying soil layer, and appears to constitute a functional barrier to tree root penetration. A photographic example is provided from Bore MDPZ9214, located in the between the Gnalka Gnoona and Koodjeepindarranna Claypans (Figure 9.3).

Generally, the shallow, massive calcrete deposits will serve to limit plant available water; there will be no capillary rise from such units and tree-roots will have limited penetration. Thus, the overlying alluvium constitutes the most favourable root zone and by inference supports the majority of tree root systems.

Table 9.4 Estimated Hydraulic Properties for Alluvium Samples near the Mulga Downs Claypans

Sample	Moisture Content			Water Yields and Availablity			Water Movement			
	Porosity (0 kPa) (%)	Field Capacity (-30 kPa) (%)	Ev Limit (-5000 kPa) (%)	Specific Yield (%)	Vadose Yield (to -5000 kPa) (%)	Total Tree-Available Water (%)	Capillary Fringe (cm)	Hydraulic Conductivity (m/d) - Saturated	Hydraulic Conductivity (m/d) - Unsaturated @ -30 kPa	Hydraulic Conductivity (m/d) - Unsaturated @ -200 kPa
MDPZ7451	36.2	19.2	0.9	17.0	18.3	35.3	100.3	0.7	1.3E-02	1.3E-05
MDPZ7449	38.7	26.5	6.8	12.2	19.7	31.9	112.1	0.2	3.2E-03	1.9E-05
MDPZ7459	41.3	5.4	0.2	35.9	5.2	41.1	0.5	4.3	2.4E-05	1.6E-08
MDPZ7449	37.6	22.3	5.2	15.3	17.2	32.4	82.4	0.3	1.8E-03	9.9E-06
MDPZ7452	39.4	29.0	7.3	10.4	21.7	32.0	138.1	0.1	4.4E-03	2.6E-05
Geometric Mean	**38.4**	**15.7**	**1.6**	**18.4**	**13.4**	**35.0**	**25.8**	**0.6**	1.2E-03	**2.5E-06**
Geometric Mean (fine samples)	**37.9**	**24.0**	**3.9**	**13.5**	**19.1**	**32.9**	**106.4**	**0.2**	4.3E-03	**1.6E-05**
Coarse Samples	**41.3**	**5.4**	**0.2**	**35.9**	**5.2**	**41.1**	**0.5**	**4.3**	**2.4E-05**	**1.6E-08**

Moisture content % vol/vol
Fine samples = silt and clay > 50% of total mass
Coarse samples = sand and gravel > 50% of total mass
Tree Water Availablility = water release between fully-saturated conditions to turgor loss (~-5000 kPa), % vol/vol
Parameters derived from PSD analysis using Saxton Rawls (2006) methodology
Sample locations shown in Figure 7.5

9.4 Vegetation Assessment

9.4.1 Potentially groundwater using vegetation

In their vegetation mapping assessment, Maia (2022) made the following comments with respect to potentially groundwater dependent ecosystems in the Study Area, inclusive of the Mulga West tenement:

- "It is possible that *E. victrix* in the vegetation types associated with the Fortescue River and associated flood-out areas, and larger drainage lines in the hills could use groundwater at some time during its life cycle i.e. *AdEv*WL, *Ev*WL, *EfEb*TG, *Bpo*Fl, ASL (2), MSL (1), MSL (2) and MTG (2)."
- *"Atalaya hemiglauca* also occurs in *AdEv*WL, *Ev*WL, ASL (2), AWL (1), MSL (1), MSL (2), MTG (1) and MTG (2) and *Melaleuca glomerata* in *AdEv*WL, *EfEb*TG, *Ev*WL, MSL (1), MSL (2) and MTG (1), and they were used (along with *E. camaldulensis*, *E. victrix* and *M. argentea* and a few other riparian species) in a Pilbara study to determine the susceptibility of riparian species to altered water regimes (Loomes 2010)."
- "In the Pilbara *M. argentea* is an obligate phreatophyte while *E. camaldulensis* and, to a lesser extent, *E. victrix* are facultative phreatophytes (Astron Environmental Services 2008 as cited in McFarlane 2015). No *E. camaldulensis* has been located during the surveys that have been carried out in the area, and neither has *M. argentea*. *E. victrix* has been the dominant eucalypt recorded in the Fortescue River system."
- "Aquatic GDEs: a national assessment has mapped the Fortescue River and associated floodplains and claypans within the [Study Area] as having high potential to be an aquatic GDE (BoM 2022a)."
- "Terrestrial GDEs: a national assessment has mapped areas of low and moderate potential to be a GDE in the [Study Area] (BoM 2022b); most of Area 4 [Mulga West to Mulga East linking corridor] and Area 5 [Two Mile Well area] are mapped as having moderate potential to be a GDE via this national assessment along with the north-western corner of Area 1 [Mulga East and Mallay Well tenements] and parts of the western edge of Area 2 [Mulga West tenement]. Much of the remainder of the [Study Area] is mapped as having low or no potential to be a GDE."

The spatial distribution of potential GDEs identified by Maia (2022) are shown in Figure 9.4. Note that these potential GDEs are based on high level species indicators, rendering them highly precautionary. More detailed assessment of vegetation using remote sensing methods was undertaken to further evaluate and refine the Maia (2022) vegetation classification (refer Section 9.5). This and other ecophysiological studies completed by AQ2 and discussed in report sections to follow present evidence that groundwater dependent vegetation is highly unlikely to occur in the Study Area.

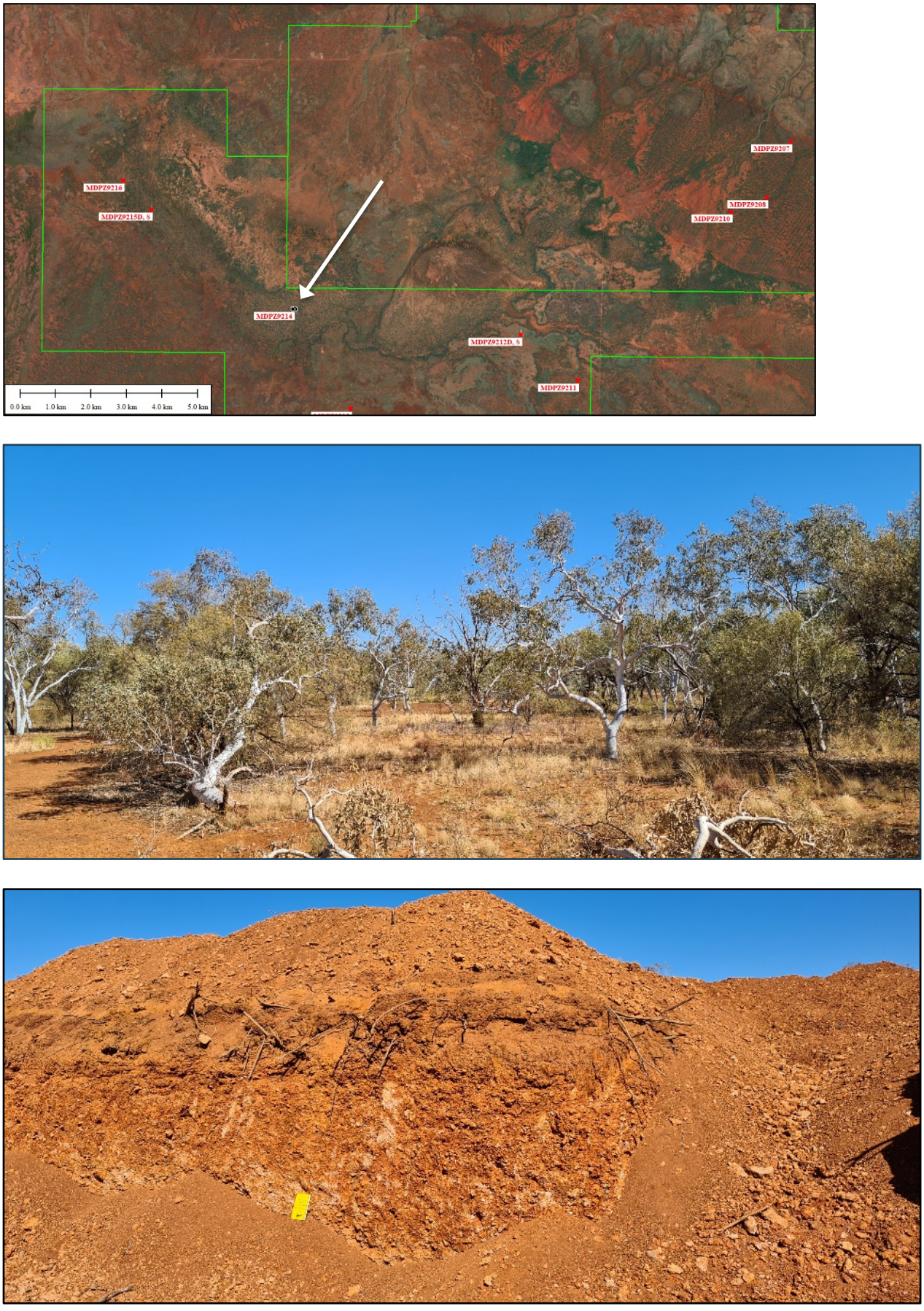


Figure 9.3 ***Eucalyptus victrix*** root systems impeded by massive calcrete at Bore MDPZ9214

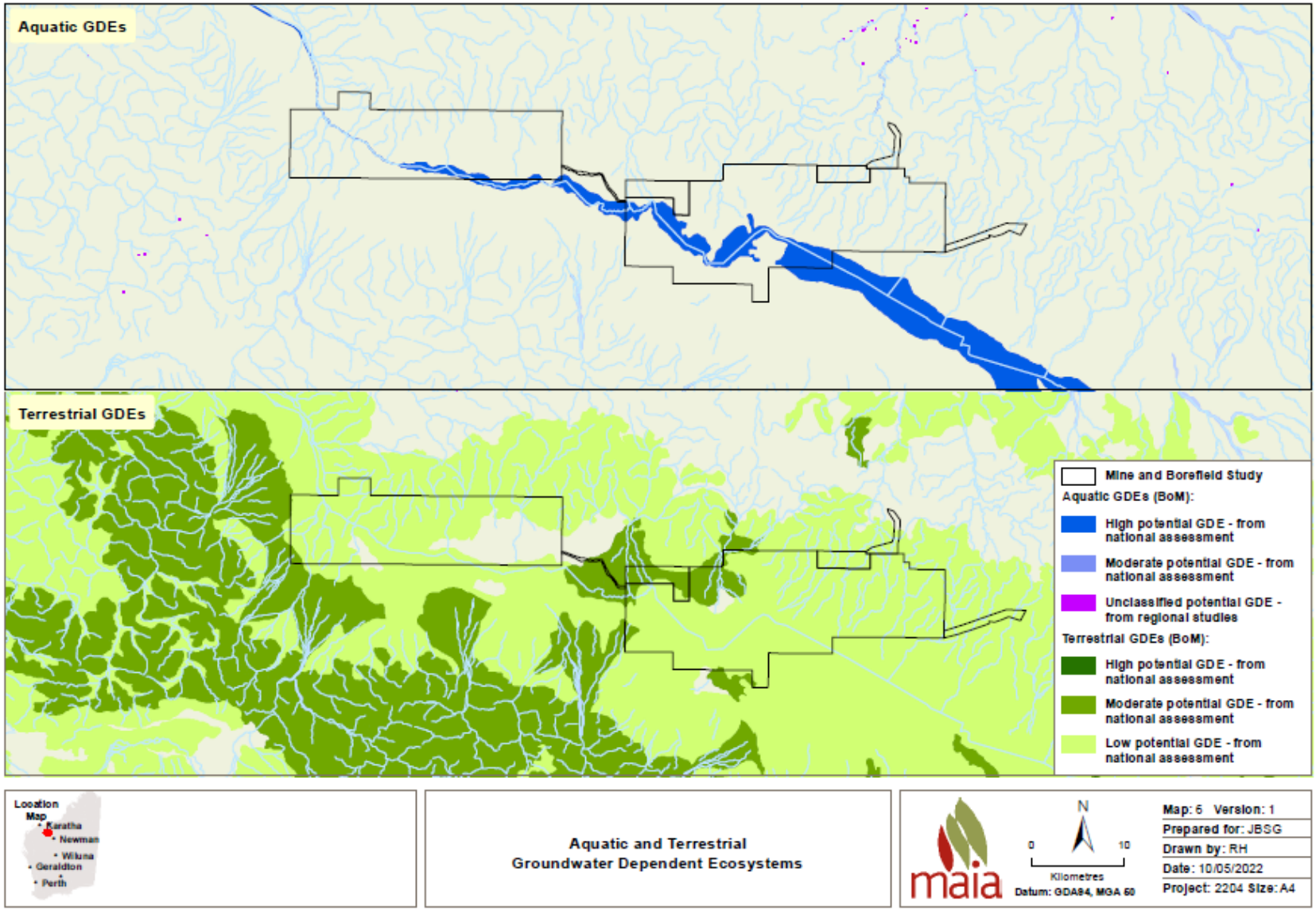


Figure 9.4 Potential GDEs in the Study Area; reproduced from Maia (2022)

9.4.2 Measured Vegetation Structure

Across all 42 plots a total of 321 trees (267 alive; 54 dead), 142 saplings (139 alive; 3 dead) and 118 shrubs (100 alive; 18 dead) were measured. Of the dead trees, 11 were classified as 'long dead and 43 as 'recently dead'. These data equate to tree mortality percentages of 27% for trees, 2% for saplings and 15% for shrubs. Plot level stem measurements are provided in Appendix S.

Structural characteristics of the *E. victrix* populations at each sampling location are described in Figure 9.5 (size-class distribution) and Figure 9.6 (stand basal area). The results are also summarised in Table 9.5. 'Mature' trees are defined as having an equivalent DBH >20 cm; these trees are estimated to be at least 20 years old. Smaller trees are referred to as 'recruits'. There appears to be a larger number of recruits at the Koodjeepindarranna Claypan than at the Gnalka Gnoona Claypan, with approximately 45% of the total number of trees having a smaller DBH than 20 cm at Koodjeepindarranna compared with 15% at Gnalka Gnoona. Notwithstanding, at Koodjeepindarranna almost 88% of the SBA comprises mature trees (i.e. the young trees are larger in number but contribute little to the overall SBA). No trees at the Koodjeepindarranna Claypan were above 800 mm DBH. In contrast, the size class distribution at the Gnalka Gnoona Claypan is more indicative of a mature, stable population structure. The highest proportion of trees (>20%) is in the 300–400 mm DBH class, with a declining trend in stem size above this. Approximately 7% of trees were above 800 mm DBH.

Table 9.5 Fortescue Valley *E. victrix* woodland structural characteristics

Claypan	No. of Plots	No. of Live Trees	Mean Equiv. Stem	All Trees		Mature Trees		Stem % Mature	SBA % Mature
				Trees/ha	SBA (m^2/ha)	Trees/ha (m^2/ha)	SBA		
Gnalka Gnoona (A_N and A_S)	21	116	494	23.0	4.4	18.7	4.3	81.0%	97.9%
Koodjeepindarranna (B-N and B_S)	21	195	321	38.7	3.4	18.8	3.0	48.7%	87.6%

In overall terms, the stand basal area of the *E. victrix* woodlands is low compared with other Pilbara ecotones; for example, riparian woodlands of major rivers in the Pilbara typically have SBA > 10 m^2/ha. The mean SBA of tree populations at the Gnalka Gnoona Claypan is somewhat higher (4.3 m^2/ha) than at the Koodjeepindarranna Claypan (3.0 m^2/ha), although the density of mature trees is similar in both claypans. The difference in SBA between the claypans, therefore, is primarily due to the difference in the size of the mature trees.

It is likely that a variety of interacting factors have contributed to the differences on tree population structure between the two claypans. Some preliminary inferences are as follows:

- The large number of young trees in the Koodjeepindarranna Claypan reflects a period of recruitment coinciding with the increase in annual rainfall since 1996 (refer Figure 2.2). This prolonged wetter period may have reduced prevailing mortality rates of recruits compared with earlier periods.
- The lower proportion of recruits at Gnalka Gnoona may be due to more intense competition from the mature trees, which are generally larger than those at the Koodjeepindarranna Claypan.
- The outcropping calcrete between the two claypans is likely to restrict surface water flow from the Gnalka Gnoona Claypan to the Koodjeepindarranna Claypan, and cause water to be retained for longer periods in the former. This would result in a longer growing period within the Gnalka Gnoona Claypan than the Koodjeepindarranna Claypan (i.e. overall more favourable soil water status), thereby contributing to larger tree size at the Gnalka Gnoona Claypan.

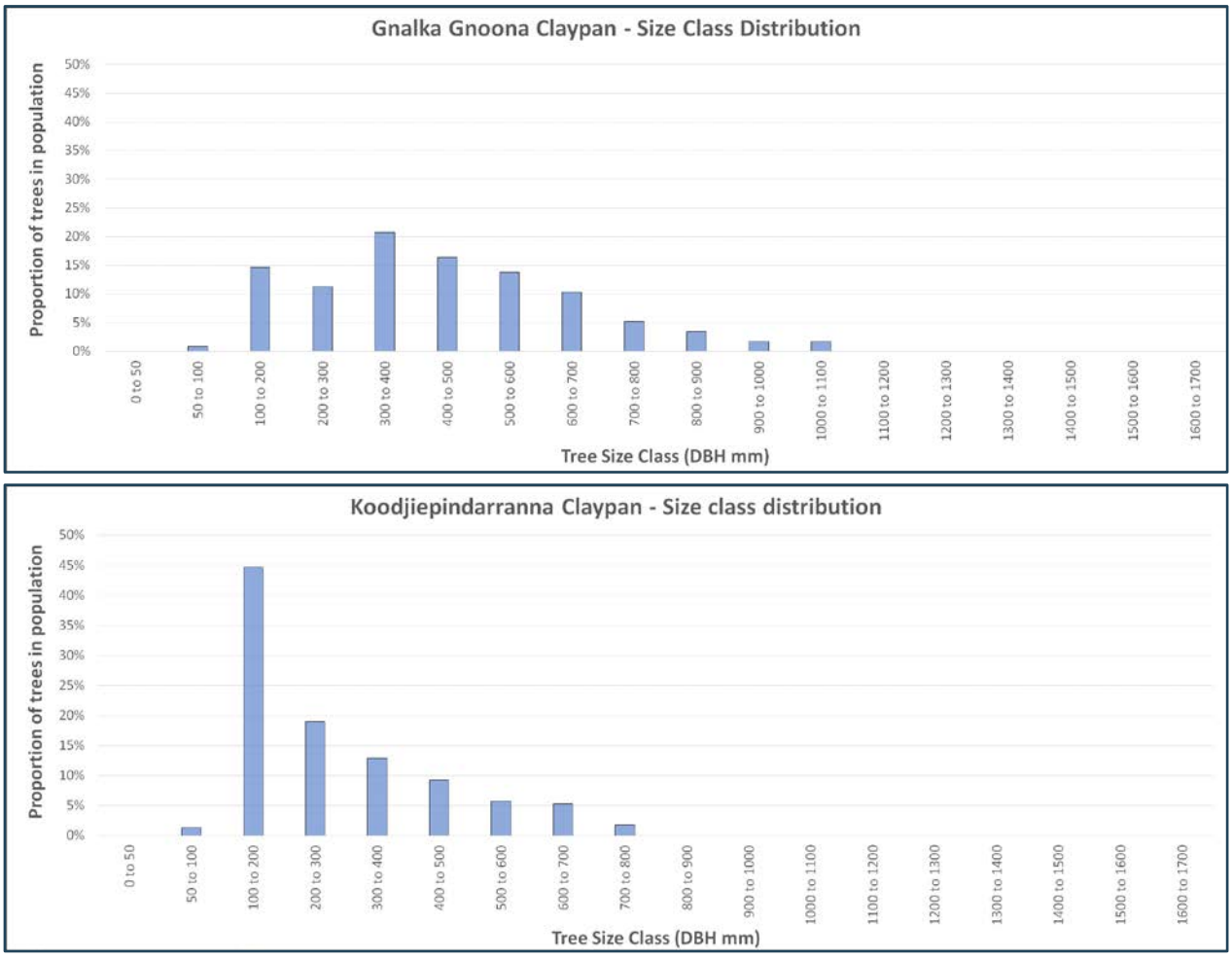


Figure 9.5 Size class distribution of *E. victrix* woodlands near the Gnalka Gnoona Claypan (A) and the Koodjeepindarranna Claypan (B)

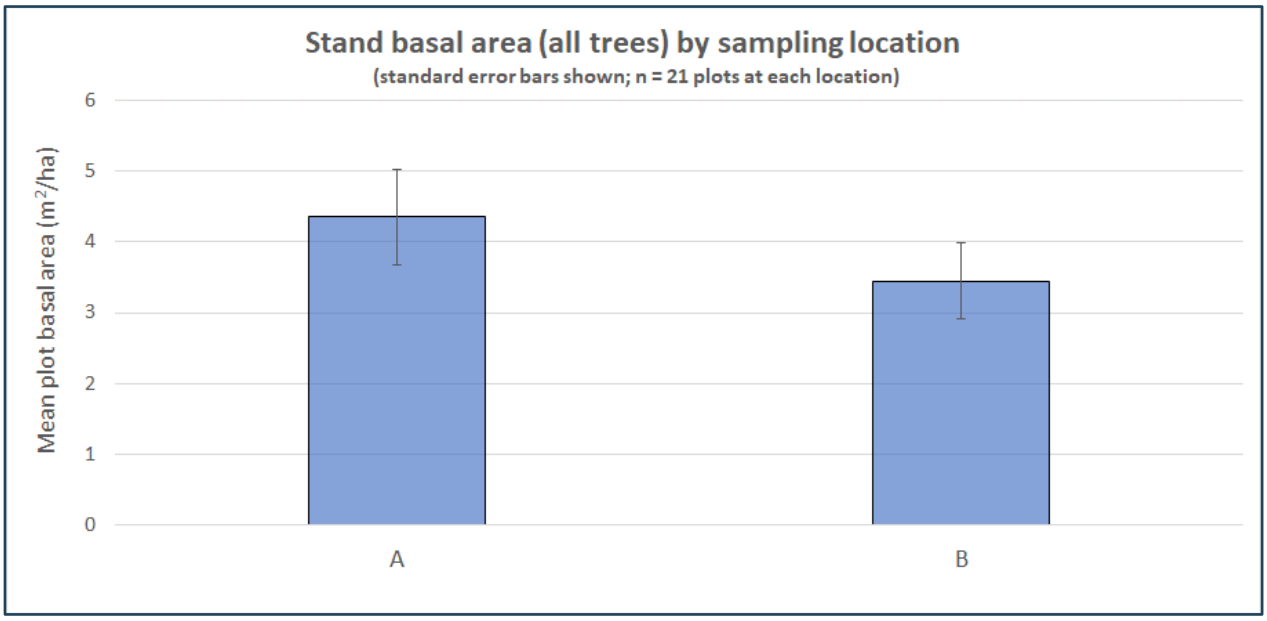


Figure 9.6 Stand basal area of E. victrix woodlands near the Gnalka Gnoona Claypan (A) and the Koodjeepindarranna Claypan (B)

9.4.3 Estimated Tree Water Use

By application of the upper and lower 'bookends' of tree water use presented in Figure 1.2 of Appendix L, the transpiration flux estimates for Sites A (Gnalka Gnoona) and B (Koodjeepindarranna) respectively are summarised in Figure 9.7. The estimated annual tree water use is in the range of 50 to 130 mm/year. Taking into account the soil profile characteristics (Section9.3.3), it is probable that this water demand can be met by the vadose zone plant available water (PAW) storage reservoir that is periodically replenished by rainfall and flooding. Further exploration of this process is provided in Section 9.7 (water balance modelling).

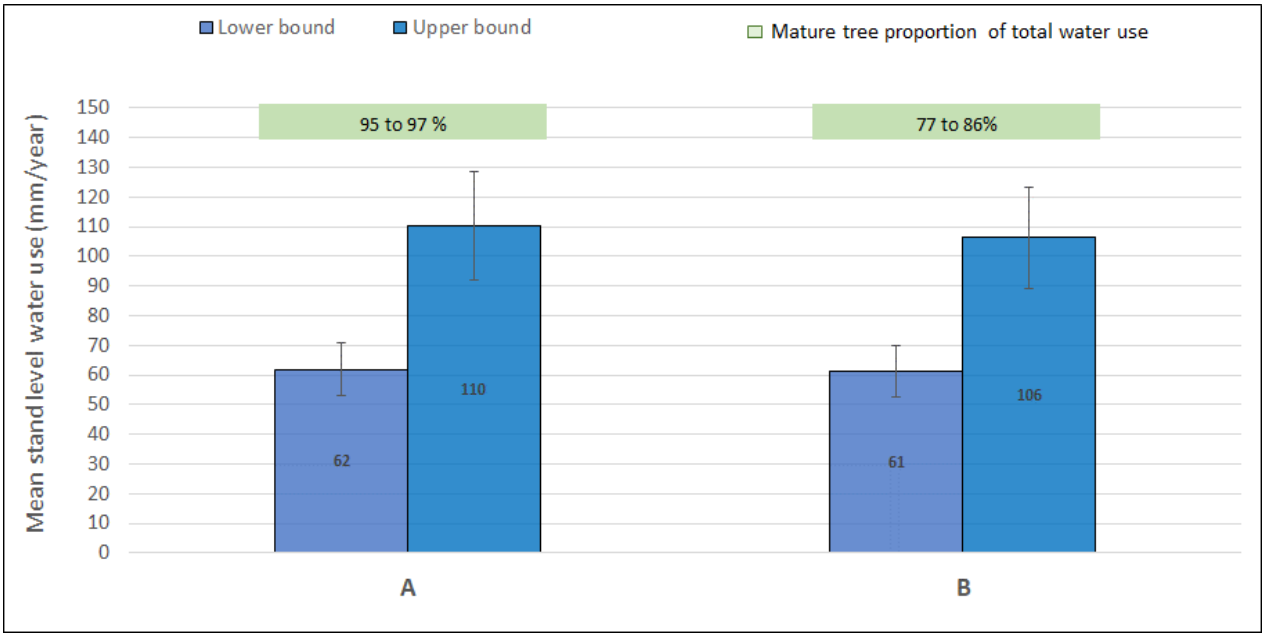


Figure 9.7 Estimated annual tree water use of E. victrix woodlands near the Gnalka Gnoona Claypan (A) and the Koodjeepindarranna Claypan (B)

9.4.4 Plant Water Status

Leaf water potential data for each sampled location are presented in the AQ2 ERI framework Figure 9.8 and Figure 9.9; the raw data is provided in Appendix T. Key observations are summarised as follows:

- At sites AN, AS, BN and BS that were originally sampled in 2019, there is a notable reduction in mean predawn Ψ_{leaf} between 2019 and 2021 (Figure 9.8). This implies that tree roots were exposed to drier and/or more saline soil in 2021 and 2022, relative to 2019. The reduction in ERI values, shown by movement towards the top left zone on the plots, indicates an increase in vegetation water stress over the period of measurements. The pattern is most pronounced at Site BS.
- At most sites the mean predawn Ψ_{leaf} is fairly consistent between October 2021 and October 2022. The exceptions were sites BS and CN, with declines of -0.47 MPa and -0.45 MPa respectively, indicating further increases in water stress at these locations.
- The pattern of change (i.e. progressive reduction in ERI) does not obviously align with antecedent rainfall in the months prior to each monitoring event, with little rain in the 4 months prior to the 2019 and 2021 October sampling events in contrast with circa 55 mm received in September 2022 (refer Figure 2.3). The results may be an artefact of site-specific soil water replenishment processes (e.g. infiltration thresholds), which have not been directly measured. Alternatively, it is possible that extensive and protracted flooding in the period December 2020 to June 2021 caused waterlogging and subsequent root dieback in the subsoil occupied by *E. victrix* roots that affected the latter measurements. This mechanism would reduce the effective rooting depth, with surviving roots confined to drier surficial layers. Further investigations are necessary to confirm this.

- When interpreting leaf water potential data, it is necessary to consider the potential for tree roots to be accessing saline groundwater. Soil water salinity contributes to an increased osmotic gradient that plants need to overcome to sustain water uptake, resulting in reduced (i.e. more negative) leaf water potentials (Mensforth et al. 1994). Hydrogeological investigations indicate that groundwater salinity near the water table proximal to the leaf water potential sampling locations is in the range of approximately 4,000 to 12,000 mg/L TDS (refer Section 6.6). By application of relationships between TDS and osmotic potential (Borg 1989) and chloride and osmotic potential (Feikema et al. 2010), this corresponds to groundwater osmotic potential of about -0.2 to -0.6 MPa.
- For all trees at all sampling locations, the minimum recorded predawn Ψ_{leaf} values were always less than the range of groundwater osmotic potential (i.e. -0.2 to -0.6 MPa) plus an allowance of -0.25 MPa for resistance within the hydraulic pathway between roots and leaves (Figure 9.10). By subtraction, this indicates a significant contribution of soil matric potential (i.e. soil dryness potentially with additive effects of vadose zone salinity) to the total soil water potential experienced by these trees. It appears that the trees are exposed to widely varying soil moisture, which is consistent with the contention that the tree roots are confined to the vadose zone (i.e. disconnected from the Fortescue Valley calcrete hosted groundwater).
- Midday Ψ_{leaf} values range between -3.2 MPa and -4.8 MPa. Lower (i.e. more negative) values tend to correspond with higher atmospheric vapour pressure deficit in October (linear coefficient of determination r^2 = 0.45).
- For sites in the West Mulga zone - at Site CN, a slight reduction in species ERI means between October 2021 and October 2022 was recorded for *E. victrix* (0.65 to 0.59), *Acacia ampliceps* (0.56 to 0.47) and *Melaleuca glomerata* (0.58 to 0.47). However, a much larger decline was observed for *Atalaya hemiglauca* (0.53 to 0.29). This may indicate that *Atalaya hemiglauca* has a shallower root system than the other species and/or lower salinity tolerance. In the case of *E. victrix* the ERI change was similar at Site CS, with ERI reducing from 0.66 to 0.60.
- The Hydroscape Area for *E. victrix* in the Fortescue Valley (pooled data - all sites) indicates that the threshold Ψ_{leaf} corresponding with stomatal closure and cessation of transpiration is about -5 MPa to -6 MPa (Figure 9.11).

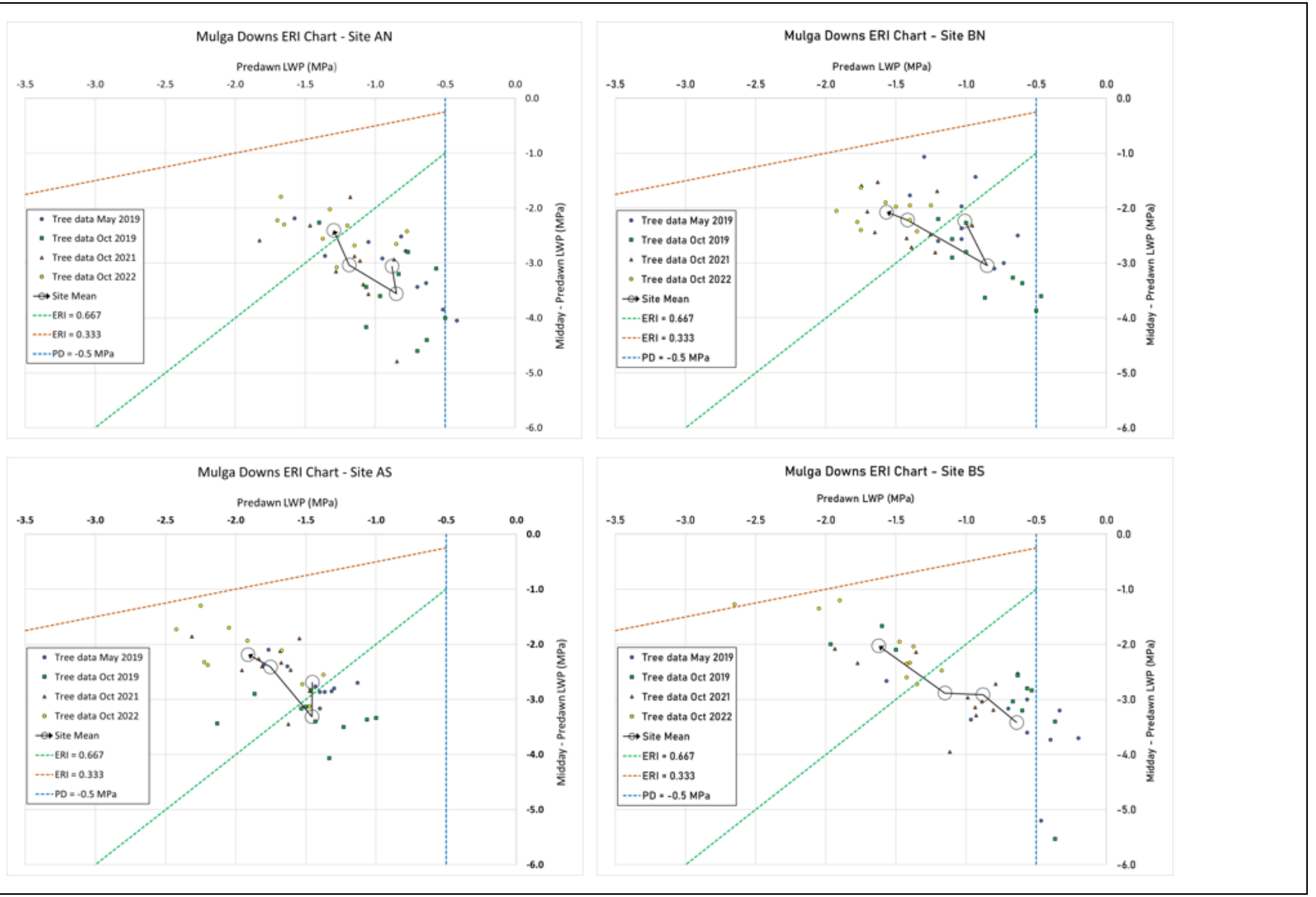


Figure 9.8 Leaf Water Potential Data from Sites AN, AS, BN and BS (near claypans)

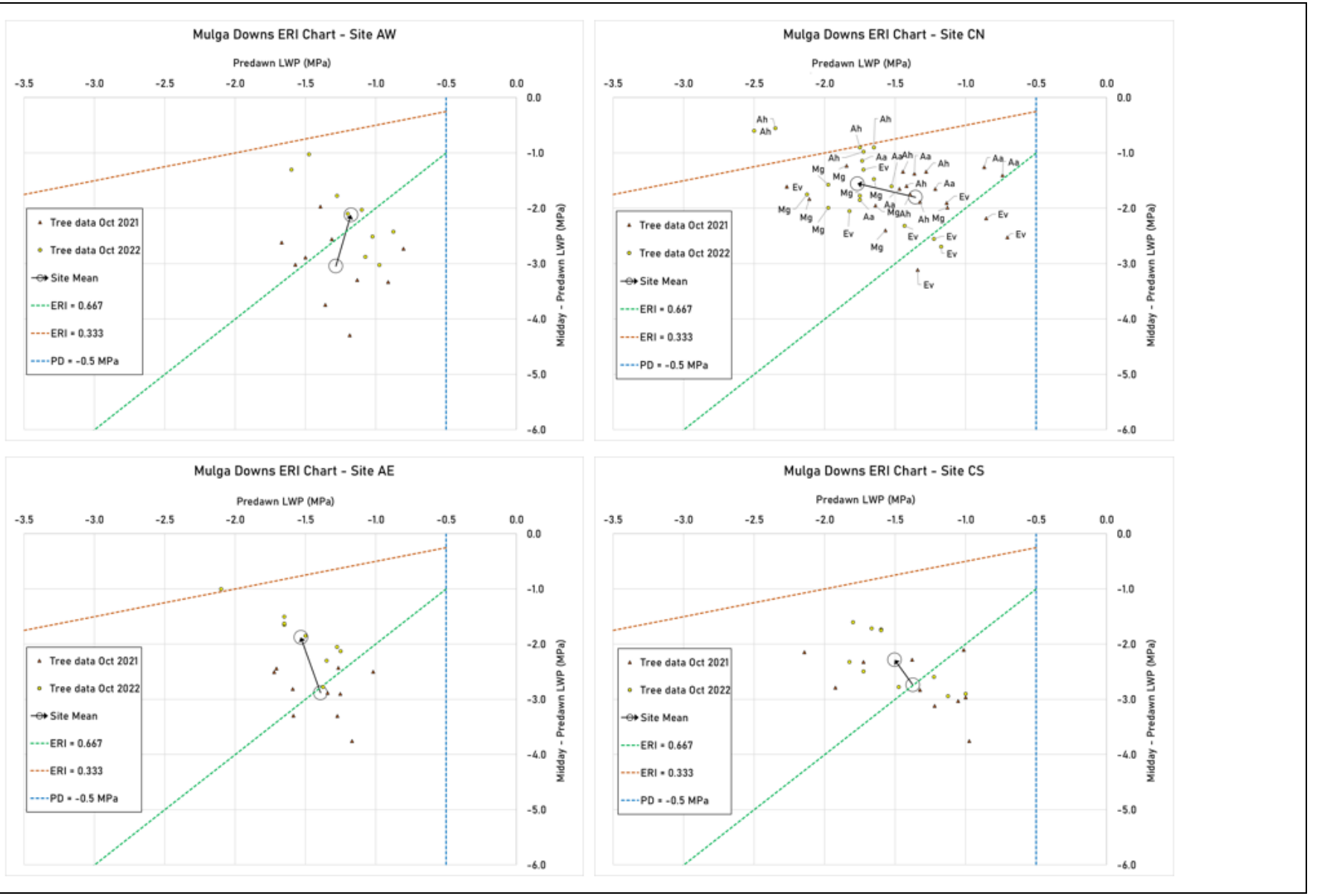


Figure 9.9 Leaf Water Potential Data from sites AE and AW (near claypans), and CN (labelled by species) and CS (Mulga West)

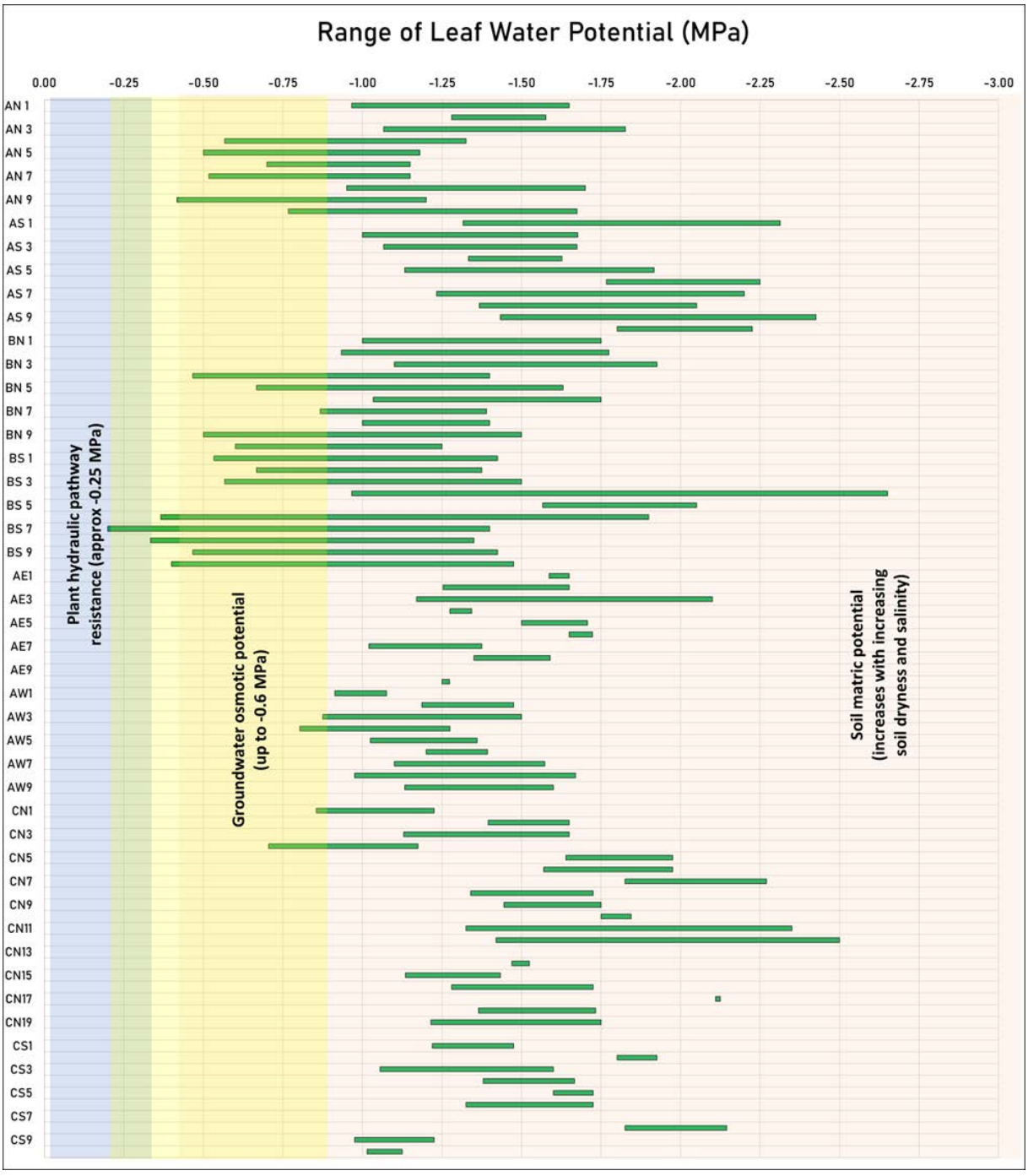


Figure 9.10 The Range of Measured Leaf Water Potentials for each tree, contrasted with factors contributing to water uptake resistance

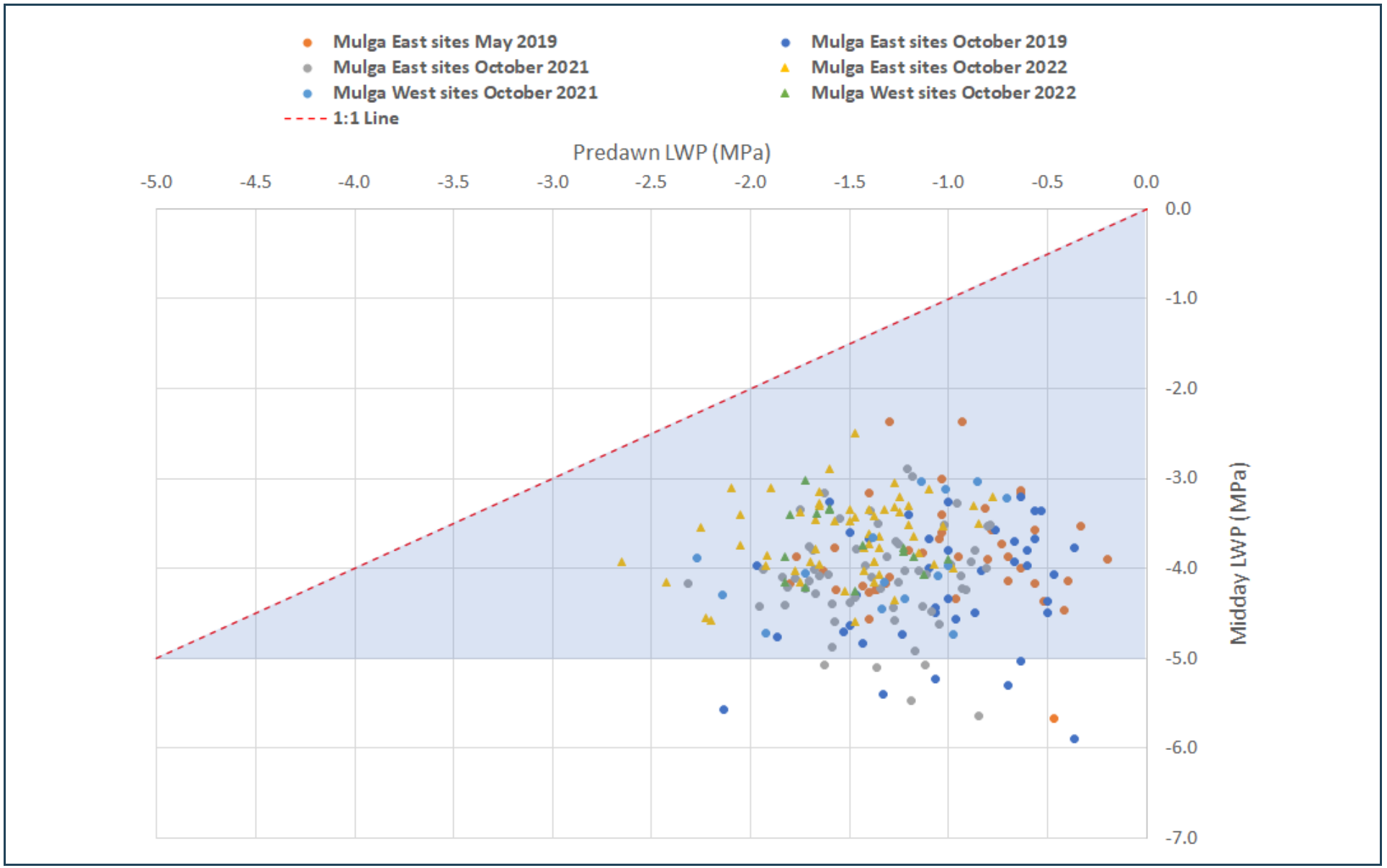


Figure 9.11 Indicative Hydroscape Area for ***E. victrix*** Trees Growing in the Fortescue Valley

9.4.5 Stem Growth

The stem growth increment for the period May 2019 to October 2022 was measured from all *E. victrix* trees that were sampled for leaf water potential in each of plots AN, AS, BN and BS (Figure 9.12). Very modest growth was observed in plots AN and AS (circa 2% increase in basal area over 41 months) and no material growth (minor stem shrinkage) in plots BN and BS. These data suggest that the trees are not using groundwater; rather they appear to be subject to prolonged water deficits and are exercising strong stomatal regulation of water use.

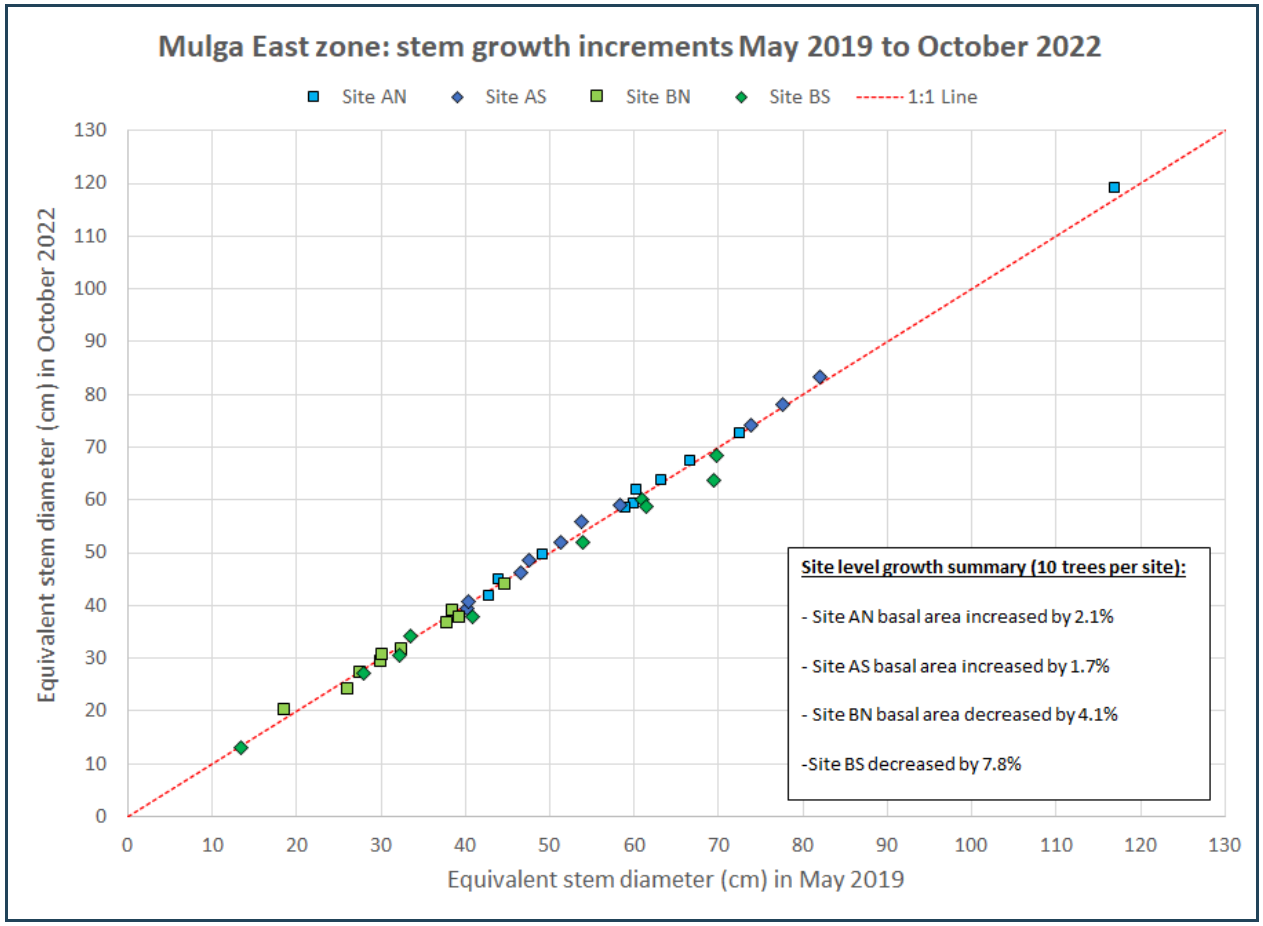


Figure 9.12 Stem Growth increments (41 months) for ***E. victrix*** trees in Plots AN, AS, BN and BS

9.5 Remote Sensing Study

Vegetation types within and adjacent to the Study Area, inclusive of the Mulga Wet tenement, were categorised according to site type and site type groups deriving from Land System mapping (Van Vreeswyk et al. 2004) (Table 9.6). Vegetation quadrat data from 211 sites, aggregated from multiple vegetation surveys, was used to determine statistical time series trends in NDVI/NDWI for each site type over an eight-month dry period following the wet summer of 2016/17 (Appendix Q).

Small areas of high and stable NDVI/NDWI (circa 30 hectares in total) were identified in association with river channel environments in the Lower Fortescue River and Hooley Creek to the north of the Mulga West tenement (Figure 9.13). However, within the Study Area such areas were spatially restricted comprising less than five hectares in total. These included:

- Sections of the Fortescue River in the northwest of the Mulga West tenement, where the river channel becomes more defined. Leaf water potential plot CN is located in a putatively similar area northwest of the Mulga West tenement.

- An area of about 1.5 ha near the eastern edge of the Gnalka Gnoona Claypan. Leaf water potential plot AE was located in this area.

Leaf water potential data collected at sites AE and CN in October 2021 and October 2022 were not indicative of groundwater use (refer Section 9.4). Relatively high and stable NDVI/NDWI at these locations is more likely to be attributable to persistent vadose storage replenished by surface inflows.

Table 9.6 Site Types and Quadrats used in Time Series NDVI/NDWI Analyses

Site Type Groups/Site Types	Quadrats
A: Hill hummock grassland	2
1. HSPG Hill spinifex grassland	1
2. HEHG Hill eucalypt spinifex grassland	1
D: Plain hummock grassland	31
5/6. PHSG/PSSG Plain hard/soft spinifex grassland	16
6. PSSG Plain soft spinifex grassland	1
8. CASG Calcrete spinifex grassland	13
13. CACS Calcrete acacia cassia shrubland*	1
F: Sheet flood hardpan plain sclerophyll shrubland	54
17. GMGW Grove mulga grassy woodland/shrubland	3
18. GMUW Grove mulga woodland/shrubland	51
I: Alluvial plain tussock grassland	52
28. APTG Alluvial plain tussock grassland	38
29. ARPG Alluvial plain Roebourne Plains grass grassland	2
33. SPSG Saline plain sporobolus grassland	8
34. SSTS Stony alluvial plain snakewood grassy shrubland	4
J: Alluvial plain halophytic shrubland	23
35. PSCS Plain snakewood shrubland with chenopod low shrubs	17
37. PSPS Plain samphire shrubland	6
K: Drainage shrubland and woodland	49
40. DESG Drainage spinifex grassland with eucalypt overstorey	3
42. DEAW Drainage eucalypt and acacia woodland/shrubland	46
Total	211

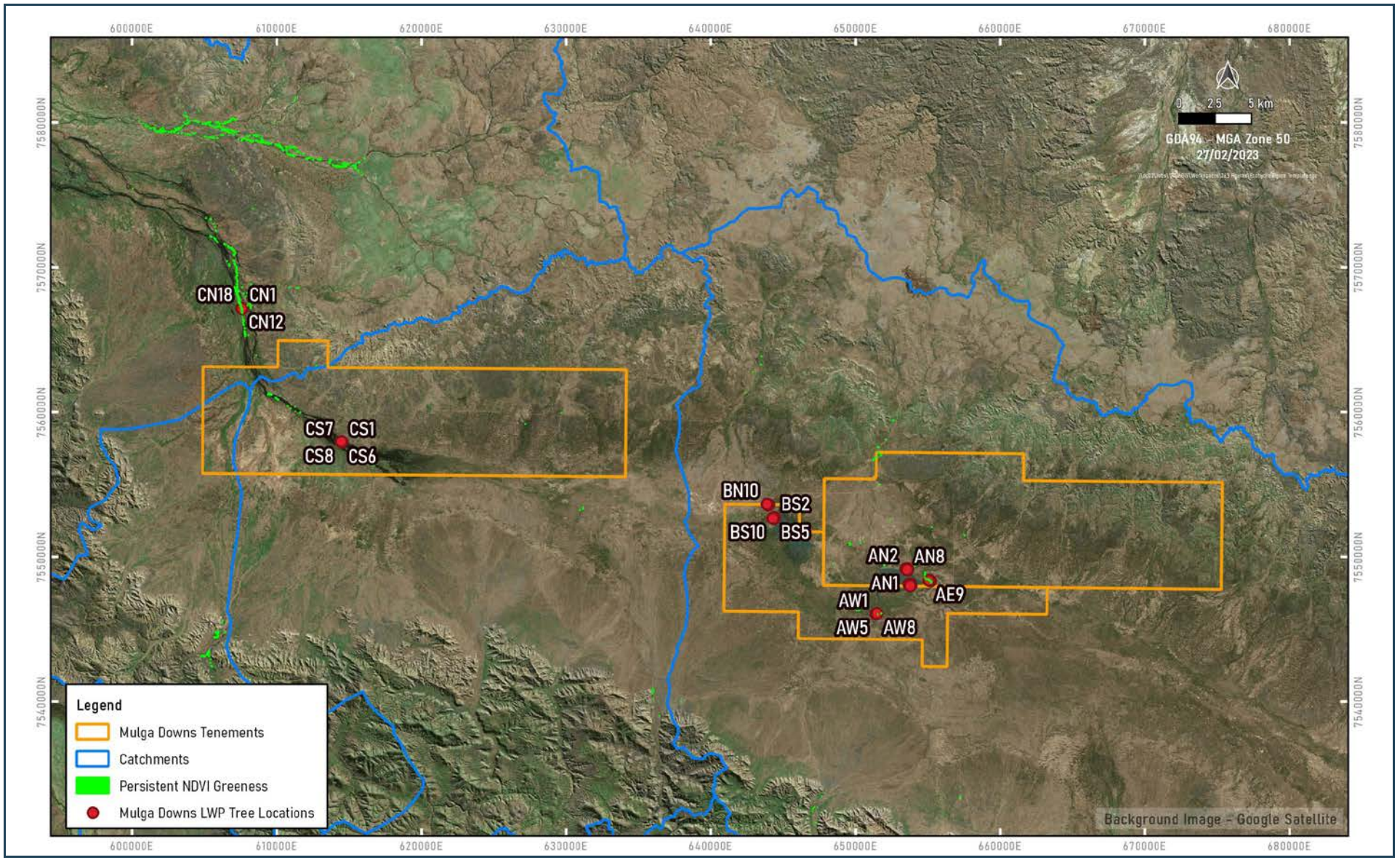


Figure 9.13 Areas of Persistently High Greenness and Wetness Identified Within and Proximal to the Study Area
Note: actual areas are small and have been buffered to be visible in this figure

9.6 Ecohydrological Conceptual Model of *E. Victrix* Woodland Communities

9.6.1 Components of the Conceptual Model

By synthesis of the assessment results described within Section 9, the conceptual ecohydrological model of *E. victrix* woodland communities fringing the claypans of the lower Fortescue Valley includes the following key elements and processes (Figure 9.14):

Elements:

- The Fortescue Valley soils are fine textured, alkaline and variably saline as influenced by flushing and evapo-concentration processes. Sandy Clay Loam to Loamy Clay surface horizons typically overlie calcrete at 50 to 100 cm depth. Within the range of potential root depths, the upper calcrete is weathered and nodular but becomes progressively massive with depth. In the absence of calcrete (e.g. where it occurs below the base of the test pits), the subsoil comprises massive, low permeability clay.
- Taking into account the gradational soil texture (i.e. becoming finer textured with depth), the maximum vadose-zone storage of plant available water (PAW) (i.e. following drainage to field capacity) is approximately 100 to 150 mm/m vertical depth.
- Non-vegetated claypans are formed in the lowest depressions, with high clay content of surface soils contributing to restricted infiltration and waterbody formation following inflow events.
- The woodland vegetation assemblage fringing the claypans and in adjacent areas comprises mature *E. victrix* trees, with a small proportion of seedlings and saplings. The understorey includes scattered *Acacia* shrubs (mainly *A. distans*), tussock grasses and small herbaceous shrubs.
- The stand basal area (SBA) of the woodland trees ranges between 2.8 and 5.7 m^2/ha. *E. victrix* trees comprise the majority of SBA and leaf area index in the woodland vegetation communities.
- The stand level transpiration flux (i.e. tree water demand) of the woodland trees ranges between about 50 and 130 mm/yr; with a positive correlation between SBA and transpiration flux.
- *E. victrix* roots are laterally expansive in the Sandy Clay Loam to Loamy Clay surface horizons. However, massive calcrete or low permeability clay impedes vertical root penetration. In addition to comprising a physical barrier, the low permeability clay contributes to prolonged subsoil waterlogging following large replenishment events.
- Groundwater is present in the calcrete at typical depths of 3 to 6 mbgl beneath the woodland vegetation communities. Groundwater salinity near the water table is in the range of approximately 4,000 to 12,000 mg/L TDS.

Processes:

- Annual replenishment of the vadose zone occurs from a combination of incident rainfall and infiltration during inundation-events. The combined contribution of rainfall and surface inflows is estimated to range between 200 mm/yr during drought conditions, 490 mm/yr during average conditions and 770 mm/yr during wet conditions (the latter have been experienced since 1996). So long as there is sufficient vadose-zone storage of plant available water (PAW), this replenishment would be enough to support the woodland vegetation without invoking and ecological requirement for deeper groundwater use. Note that within the vadose zone, depending on soil hydraulic properties, transient perched layers of saturation may periodically develop and be used by trees.
- Soil moisture in the root zone progressively reduces in between replenishment events; as indicated by time series leaf water potential measurements with predawn LWP <-0.5 MPa. This triggers conservative water use behaviour by the trees (i.e. stomatal closure) and reduced growth. Based on midday LWP measurements, cessation of transpiration by *E. victrix* is estimated to occur at approximately -5.0 MPa. Owing to low soil hydraulic conductivity and/or the presence of massive calcrete, soil water replenishment by capillary rise from the water table is minimal.

- It is estimated that there is sufficient rainfall to at least partially inundate the claypans every two years on average. Infiltration appears to occur over a prolonged period of several months following inundation, owing to impeded percolation in the subsoil. Consequently, evaporation from the waterbodies is the major loss term and this is associated with progressive salinity increase in the waterbodies. Ponded water contributes to moisture availability in the vadose zone around the claypan waterbody fringes. Subsoils may become periodically waterlogged.
- Subsoil percolation, although strongly attenuated, is sufficient to flush salt deriving from evapo-concentration in the vadose zone into the underlying groundwater system.
- Surface throughflows during the largest flood events is infrequent but assumed to also contribute to salt flushing from the system.

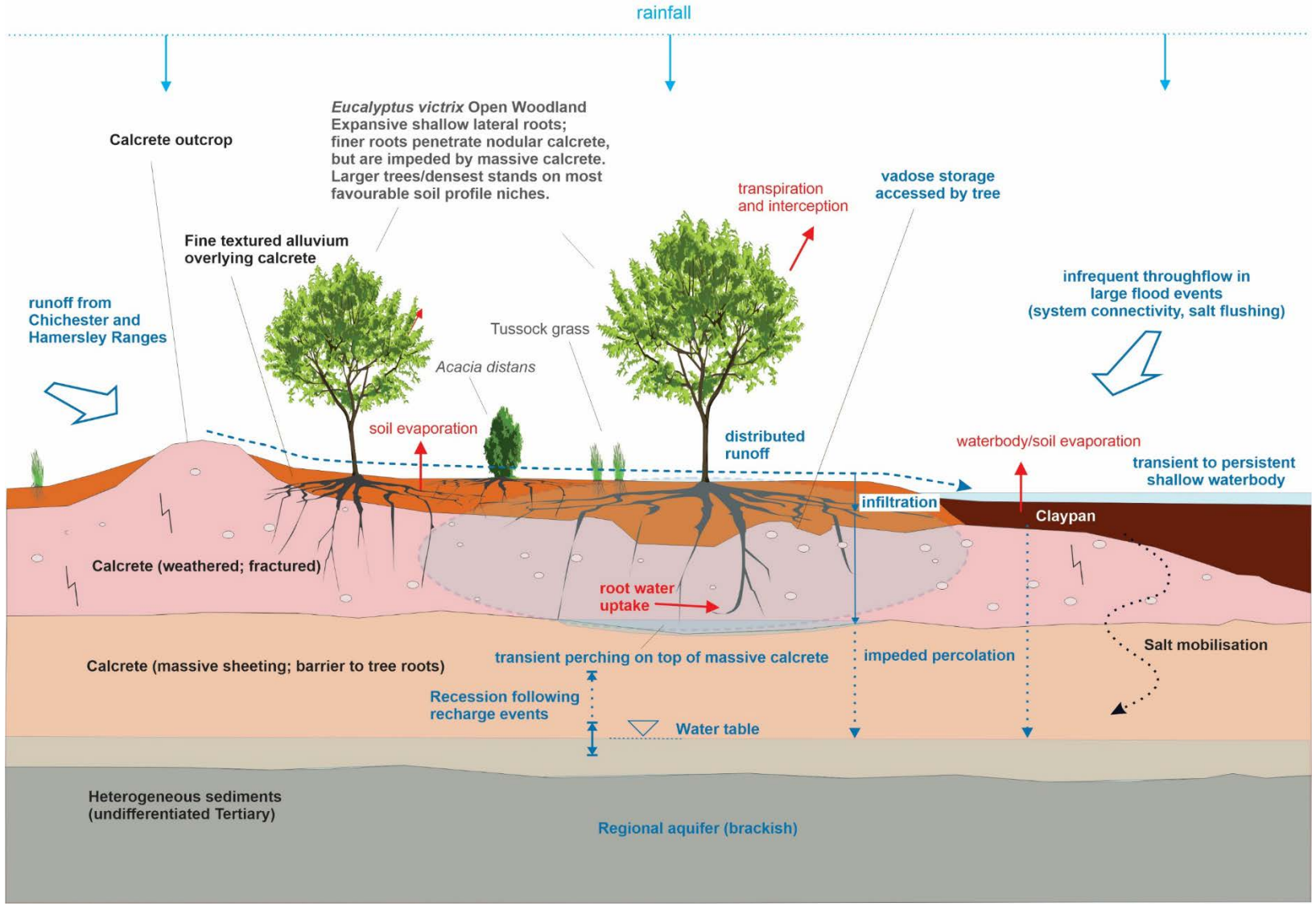


Figure 9.14 Conceptual Ecohydrological Model of the ***Eucalyptus victrix*** Woodland Communities

9.7 Water Balance Model

9.7.1 Overview

The conceptual ecohydrological model was used to formulate an ecohydrological water balance model (EWB), to further evaluate the conclusions described in Section 9.6 (i.e. that *E. victrix* trees in the Fortescue Valley coincident with the Study Area are unlikely to use or rely on groundwater). The modelling objective was to determine the frequency and magnitude of drought stress experienced by the woodland trees over extended periods. This provides a basis for evaluating the likelihood of groundwater being necessary to augment rainfall at key times over these periods (i.e. after prolonged soil drying).

The EWB evaluates water transfers in *E. victrix* woodlands that are representative of the tree measurement locations in the vicinity of the claypans. In the model, the only water source available to the trees is vadose zone soil water, which is replenished by infiltrated rainfall (i.e. no surface or subsurface lateral water inputs, and no groundwater connection). The EWB is therefore conservative with respect to surface water inputs, given that flooding inundation of the woodland vegetation communities does occur during larger flood events. The mechanistic basis of the EWB is further described in Table 9.1 and schematically depicted in Figure 9.1.

The Base Case scenario was defined as:

- Average climate conditions based on SILO rainfall and ETo data for the period 1962 – 1966 (Figure 9.15). This period corresponds with mean annual rainfall of 369 mm and potential ETo of 2,134 mm.
- Canopy cover = 25%.
- SBA = 5 m^2/ha.
- Soil profile depth available to plant roots = 100 cm. Tree roots occupy the full model domain.
- Soil type = Clay Loam (29% Sand; 32% Clay). The maximum PAW storage of Clay Loam is 91 mm per 100 cm of soil depth. In all model scenarios the starting soil moisture is 75% of field capacity, which was considered to be suitably representative based on examination of model scenario end points.
- Transpiration function – a sigmoid function of the following form:

  $$T = Tmax \times \frac{1}{\left(1 + \left(\frac{\Psi soil}{-1.2}\right)^3\right)}$$

  This function depicts high water use at high matric potential, with strong down regulation (i.e. stomatal control) as the soil profile dries out. This is consistent with the strongly isohydric behaviour of *E. victrix* as determined by leaf water potential measurements (refer Section 9.4.4).

Relationships between the key fluxes and elements were defined such that the water balance was internally consistent (i.e. water in = water out + change in storage). The model is run on a daily time-step over a 5-year simulation period. However, the results have been presented as annual averages for the period.

Sensitivity analysis comprised:

- Two alternative climate sequences:
  - "Wet" based on SILO rainfall and ETo data for the period 1996 – 2000 (Figure 9.15). This period corresponds with mean annual rainfall of 590 mm and potential ETo of 2,082 mm.
  - "Dry" based on SILO rainfall and ETo data for the period 1949 – 1953 (Figure 9.15). This period corresponds with mean annual rainfall of 205 mm and potential ETo of 2,184 mm.

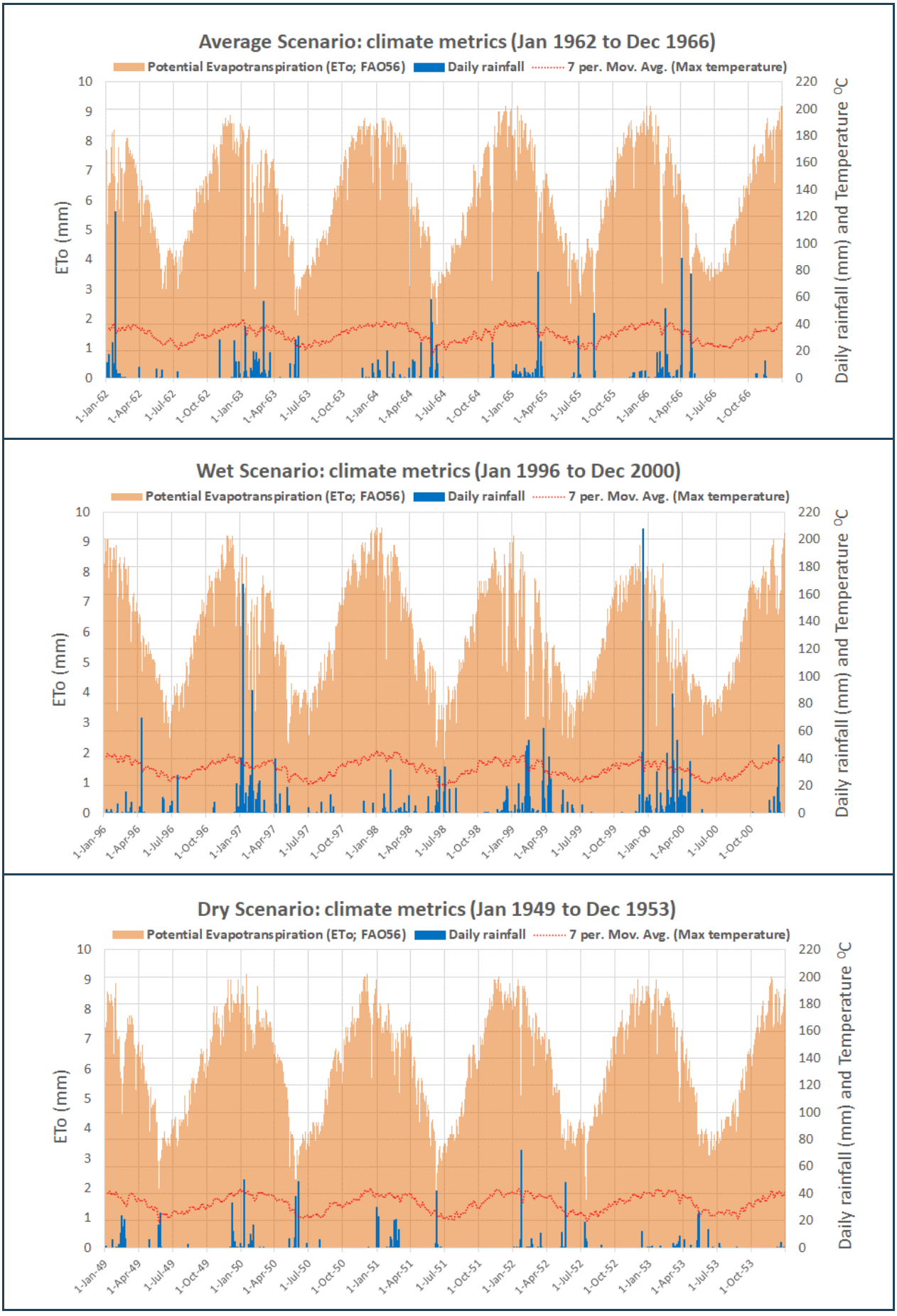


Figure 9.15 Climate Sequences used in EWB Modelling Scenarios

- Three alternative soil types with hydraulic attributes consistent with Saxton and Rawls (2006):
  - Sandy Loam (63% Sand; 10% Clay); maximum PAW storage is 77 mm per 100 cm of soil depth.
  - Silt Loam (16% Sand; 18% Clay); maximum PAW storage is 116 mm per 100 cm of soil depth.
  - Clay (32% Sand; 55% Clay); maximum PAW storage is 67 mm per 100 cm of soil depth.
- Two alternative transpiration functions, which are considered to provide plausible upper and lower bounds of the water regulation behaviour of *E. victrix* trees:
  - CURVE 1 - the 'default' curve of Sperry et al. (2016). This function depicts a conservative water use strategy (i.e. strong stomatal regulation at relatively high soil matric potential).
  - CURVE 3 - 'high sigmoid cavitation resistance' curve of Sperry et al. (2016). This function depicts a non-conservative water use strategy, where relatively high soil water extraction is maintained at low soil matric potential.
- For the Base Case scenario:
  - Evaluation of increased and decreased SBA (range = 3 to 10 m^2/ha). As per the relationship shown in Figure 1.2 in Appendix L, one unit change in SBA changes stand annual water demand by about 25 to 30 mm. To account for the effect of changing tree density on canopy cover, a relationship between Canopy Cover and SBA was derived from measured trees and high-resolution aerial imagery as shown in Figure 9.16. For reasons of model parsimony, no adjustment was made to the zone of tree root occupation for different SBA values (i.e. the full model domain is occupied). However, it is recognised that full root occupancy becomes less realistic at low tree densities.
  - Evaluation of increased and decreased soil profile depth available to plant roots (range 50 to 200 cm).

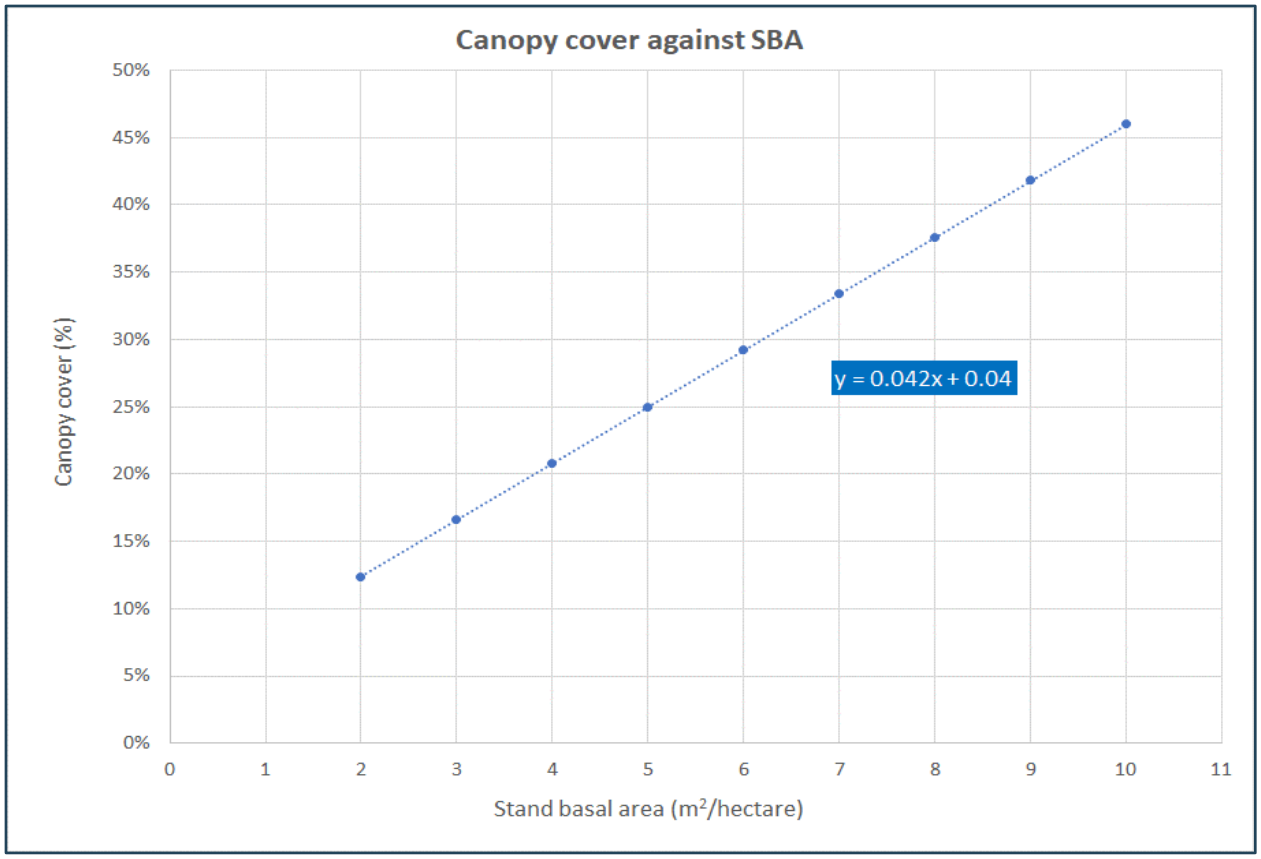


Figure 9.16 Relationship between Canopy Cover and SBA used in EWB Model Sensitivity Analyses

9.7.2 Drought Stress

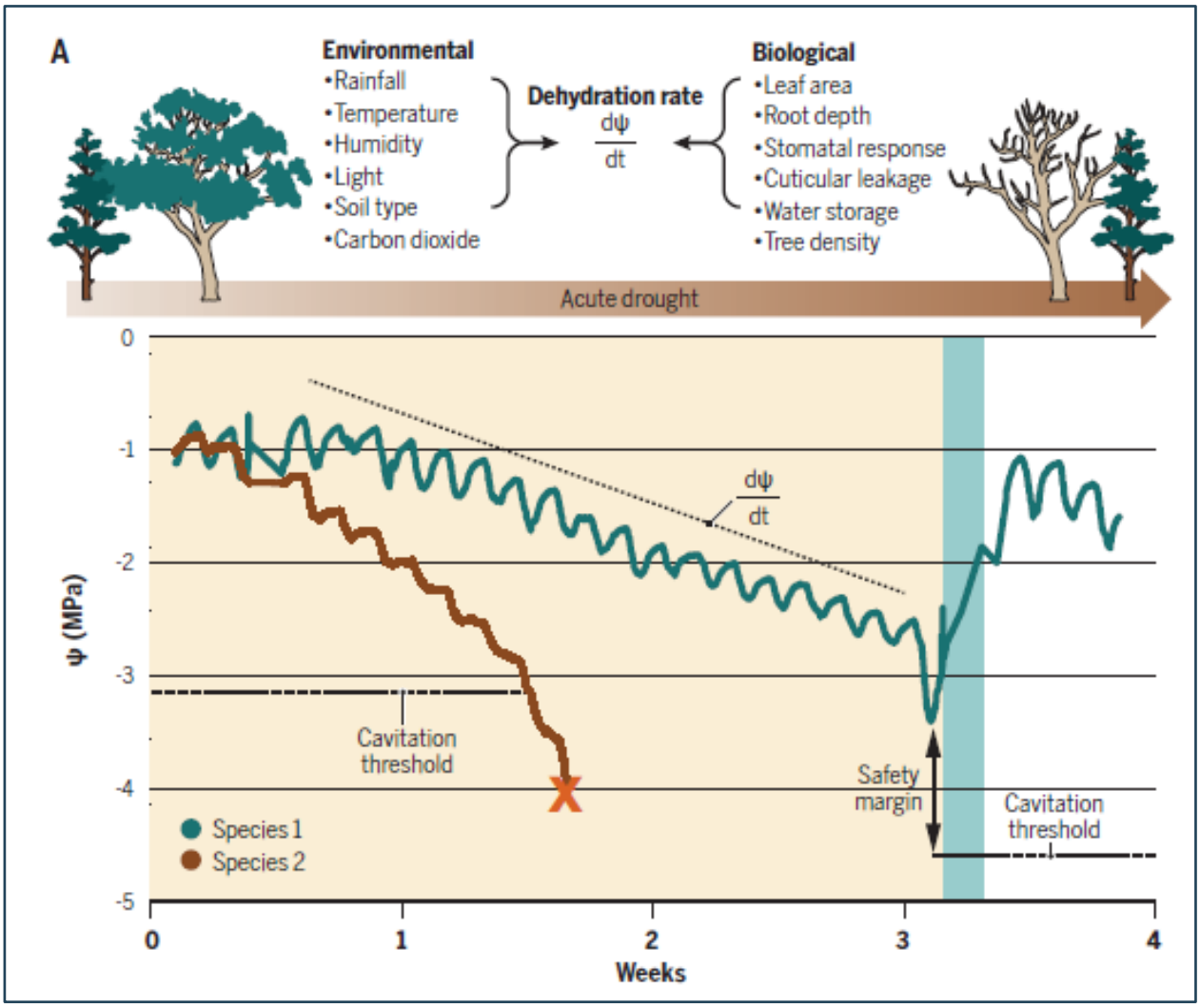
As plant available water (PAW) in the soil profile available to tree roots becomes depleted, trees progressively down-regulate their water use by reducing stomatal conductance (Cai et al. 2023). Typically, stomatal closure anticipates hydraulic failure of the xylem, with the leaf water potentials at which stomata close being less negative than those at which the xylem cavitates. This coordination between stomatal closure and hydraulic limitations is a well-accepted principle of plant water relations.

Soil drought stress occurs when the soil water supply is unable to sustain the transpiration demand. Arid zone plants have adaptations to avoid or tolerate and recover from drought stress, in particular acute drought stress. However, prolonged exposure to drought is associated with tree health decline as documented in numerous case studies in Australia and elsewhere (e.g. Keppel et al. 2023; Losso et al. 2022; Wright et al. 2023; Chen et al. 2021).

With the progression of drought conditions, tension within the water-conducting xylem will increase as plants dehydrate via water loss through permeable leaf cuticles and leaky stomata. Without relief, increasing xylem tension can cause cavitation and widespread embolism (i.e. air bubbles that block water transport in the hydraulic pathways within the plant), leading to turgor loss, hydraulic dysfunction and ultimately plant death (Brodribb et al. 2020; Verslues et al. 2023). In conjunction with hydraulic failure, drought stress can also increase the vulnerability of trees to other mortality factors such as heatwaves, carbon starvation, pests and diseases (McDowell et al. 2022). Quantification of drought stress is complicated by variable responses within and between species, and the dynamic ability of individual plants to adjust to drought exposure (e.g. osmotic adjustment by accumulation of leaf solutes). Experimental studies on a variety of plant species have found that the critical level of hydraulic dysfunction, referred to as the cavitation threshold, typically occurs within days to several weeks from the point of full stomatal closure (Blackman et al. 2019; Barkaoui and Volaire 2023). This process is schematically described in Figure 9.17.

Cavitation thresholds for *E. victrix* trees in the Fortescue Valley have not been directly determined. However, based on the preceding discussion, the severity of soil drought can be characterised by the degree and duration of soil drying and the impact of this on tree transpiration rates. With respect to interpretation of the EWB results:

- Drought stress was defined as occurring when the transpiration flux is less than 30% of Tmax (i.e. T <0.30 x Tmax).
- Severe drought stress was quantified as the number of consecutive days that trees experience drought stress (i.e. T <0.30 x Tmax). This is considered to indicate a moderate risk of cavitation thresholds being exceeded.
- Extreme drought stress was quantified as the number of consecutive days when the transpiration flux is less than 10% of Tmax (i.e. T <0.10 x Tmax). This is considered to indicate a high risk of cavitation thresholds being exceeded.



Brodribb et al. (2020):

'A representation of the impact of drought on two tree species with different thresholds for drought-induced vascular damage. Different xylem cavitation thresholds determine the water potential (Y: water stress intensifies as water potential becomes more negative) causing tree mortality. Two lines indicate the oscillating water stress between day and night as the two species (indicated by small tree icons) dehydrate after the cessation of rainfall (data are from two trees from a dry forest site in Tasmania, Australia). The cavitation threshold and the rate of drying (dY/dt) both determine how many days into an acute drought each species will die. The taller species, which is more vulnerable to cavitation and faster drying, dies (indicated by an orange X) in week 2, whereas the shorter species survives until rainfall (indicated by the blue rectangle in week 3), enabling the tree to recover hydration. The proximity between the cavitation threshold and the lowest water potential during drought is known as the hydraulic safety margin. The dehydration rate is a product of a set of environmental and biological factors, many of which interact. Increasing temperature increases the rate of drying both directly and by interaction with biological factors, whereas CO2 has the potential to reduce dehydration by its biological interaction with stomata and the photosynthetic rate.'

Figure 9.17 Theoretical Impacts of Drought on Different Tree Species (reproduced from Brodribb et al. 2020)

9.7.3 Results

9.7.3.1 Average Climate

Results for the set of Average climate scenarios are presented in Table 9.7 and Figure 9.18; with key findings summarised as follows:

- Effective rainfall was 351 mm/year.
- Soil evaporation was estimated to be 191 to 203 mm/year.
- Tree water use was estimated to be 121 to 148 mm/year (circa 76 to 92% of upper bound).
- Groundwater recharge was estimated to be 6 to 27 mm/year (i.e. circa 2-8% of effective rainfall).

Drought stress metrics are shown in Figure 9.19, with key findings summarised as follows:

- The total number of severe drought stress days ranged from 0 to 187 over the five-year (1,826 day) period (i.e. up to 10% of days). Relatively small differences between soil types are evident, with a negative correlation between soil PAW storage capacity and drought severity i.e. Silt Loam has lowest drought exposure whilst Clay has highest drought exposure. With respect to transpiration functions, the Base Case and CURVE 3 functions give very similar results. The more conservative transpiration function (CURVE 2) is associated with lower stand transpiration, slower depletion of soil water reserves and hence less drought stress.
- The maximum duration of severe drought stress ranged from 0 to 97 days.
- There were no days of extreme drought stress.

These results suggest that the ecological water requirements of the *E. victrix* woodland at SBA =5 m^2/ha and available soil depth of 100 cm are sustained under average rainfall. Drought exposure is seasonal and neither extreme or prolonged. Under these conditions, trees would be expected to maintain growth and remain in reasonable health. It is highly unlikely that the trees require groundwater to meet their water use requirements.

9.7.3.2 Wet Climate

Results for the set of Wet climate scenarios are presented in Table 9.2 and Figure 9.20; with key findings summarised as follows:

- Effective rainfall was 562 mm/year. Notwithstanding, it is notable that some extended relatively dry periods did occur through the 5-year sequence (i.e. in Year 1 and Year 3; refer Figure 9.15). A major replenishment event occurred in January 2000, which provided ample soil water reserves for the following 12 months even though ongoing rainfall in 2000 was minimal.
- Soil evaporation was estimated to be 251 to 261 mm/year.
- Tree water use was estimated to be 113 to 157 mm/year (circa 70 to 98% of upper bound).
- Groundwater recharge was estimated to be 130 to 168 mm/year (i.e. circa 23 to 30% of effective rainfall).

Drought stress metrics are shown in Figure 9.21, with key findings summarised as follows:

- The total number of severe drought stress days ranged from 0 to 274 over the five-year (1,826 day) period (i.e. up to 15% of days). The Clay soil type corresponded with higher drought stress in comparison with the other soil types. This can be explained by the lower PAW storage capacity of the Clay soil and length of relatively dry periods within the 5-year climate sequence.
- The maximum duration of severe drought stress ranged from 0 to 111 days, which is similar to the Average scenarios. During the wetter phases within the sequence, a significant portion of rainfall percolated past the tree root zone and contributed to groundwater recharge.

- There were no days of extreme drought stress.
- In overall terms, the degree of drought stress was similar for the wet and average climate scenarios. Under the wet scenario much of the extra water delivered by rainfall either evaporates at the soil surface or becomes groundwater recharge.

These results suggest that the ecological water requirements of the *E. victrix* woodland at SBA =5 m^2/ha and available soil depth of 100 cm are exceeded when rainfall is above average. However. drought exposure still occurs during dry phases within the sequence and the sustainable SBA is primarily controlled by soil water storage capacity and the length of time between substantial soil water replenishment events. Under these conditions, trees would be expected to remain in good health and display reasonable growth rates.

9.7.3.3 Dry Climate

Results for the set of Dry climate scenarios are presented in Table 9.9 and Figure 9.22; with key findings summarised as follows:

- Effective rainfall was 195 mm/year.
- Soil evaporation was estimated to be 117 to 136 mm/year.
- Tree water use was estimated to be 57 to 91 mm/year (circa 36 to 57% of the upper bound).
- There was no groundwater recharge under any scenario.

Drought stress metrics are shown in Figure 9.23, with key findings summarised as follows:

- The total number of severe drought stress days ranged from 306 to 921 over the five-year (1,826 day) period (i.e. 17 to 50% of days). Notably there was a general trend of worsening drought stress over the period, associated with progressive soil water depletion.
- The maximum duration of severe drought stress ranged from 149 to 256 days.
- The maximum duration of extreme drought stress ranged from 5 to 118 days.

These results suggest that under below average rainfall, *E. victrix* woodland trees at SBA =5 m^2/ha and soil depth of 100 cm are exposed to significant and repeated drought stress. Under these conditions trees growth would be minimal, tree health decline (i.e. crown dieback) would be expected. Sustained drought stress could potentially result in tree deaths and hence SBA adjustment via 'self-thinning' within the woodland stands.

9.7.3.4 Altered Stand Basal Area and Soil Depth

The results from the SBA and soil depth sensitivity analyses, applicable to the Clay Loam soil type, are presented in Figures 9.10, 9.11 and 9.12 for Average, Wet and Dry scenarios respectively. Key findings are summarised as follows:

- In overall terms:
    - Drought stress (i.e. total number of days when T <0.30 x Tmax) is highly sensitive to changes in SBA. It can be anticipated that more intensive between tree competition and restricted growth would occur at higher SBA.
    - Severe and extreme drought stress (i.e. number of consecutive days with T <0.30 x Tmax or T <0.10 x Tmax respectively) is less sensitive to changes in SBA. Note that any of multiple periods of extreme drought stress has the potential to cause tree health decline and SBA adjustment. This result reaffirms the overriding importance of the timing and magnitude of soil water replenishment events, rather than total annual rainfall per se, for sustaining SBA.

- Drought stress and severity indicators are highly sensitive to the soil profile depth available to plant roots, where depth progressively decreases from 75 cm. However, exposure to drought stress rapidly declines as soil depth increases from 125 cm. Although this would be expected on the basis of increased PAW storage, it is important to note that a contributing factor is also the starting soil moisture condition used in the model (75% of field capacity). This starting soil moisture content may be less realistic at greater soil depths, which require larger replenishment events to "re-fill the bucket".

- Under Average climate:
  - In the case of altered SBA, there is no manifestation of extreme drought stress until SBA = 7 m^2/ha, which corresponds with a maximum duration of extreme drought stress of 64 days.
  - In the case of altered soil depth, there is no manifestation of extreme drought stress until the soil depth is reduced to 50 cm, which corresponds with a maximum duration of extreme drought stress of 68 days.
  - By inference, the ecological water requirements of the *E. victrix* woodland are likely to be met by direct rainfall under the following SBA and soil depth combinations:
    - Soil depth = 50 cm; SBA up to approx. 4 m^2/ha.
    - Soil depth = 100 cm; SBA up to approx. 6 m^2/ha.
    - Soil depth >150cm; SBA up to approx. 8 m^2/ha.
  - For woodland stands to achieve higher SBA, in the absence of a groundwater resource accessible to trees, either deeper soil conferring greater vadose storage and/or surface inflows that augment direct rainfall replenishment of storage from the surface are necessary.
- Under Wet climate:
  - The results are materially the same as those for the Average climate. This highlights the overriding importance of the timing and magnitude of soil water replenishment events, rather than total annual rainfall per se, for sustaining SBA. Soil water replenishment is a function of rainfall event size and antecedent soil moisture. Indicatively, a rainfall threshold of about 20 to 25 mm is typically needed to deliver significant vadose zone replenishment (>10 mm) based on the model outputs.
- Under Dry climate:
  - The pattern of drought exposure is similar to the Average and Wet climate scenarios, but with the SBA threshold for chronic stress exposure shifted down by about 2 units (i.e. sustainable SBA reduces from about 6 to 4 m^2/ha). This finding supports that contention that prolonged below rainfall sequences are likely to have associated tree health decline (i.e. crown dieback) and SBA adjustment (i.e. selective tree deaths).

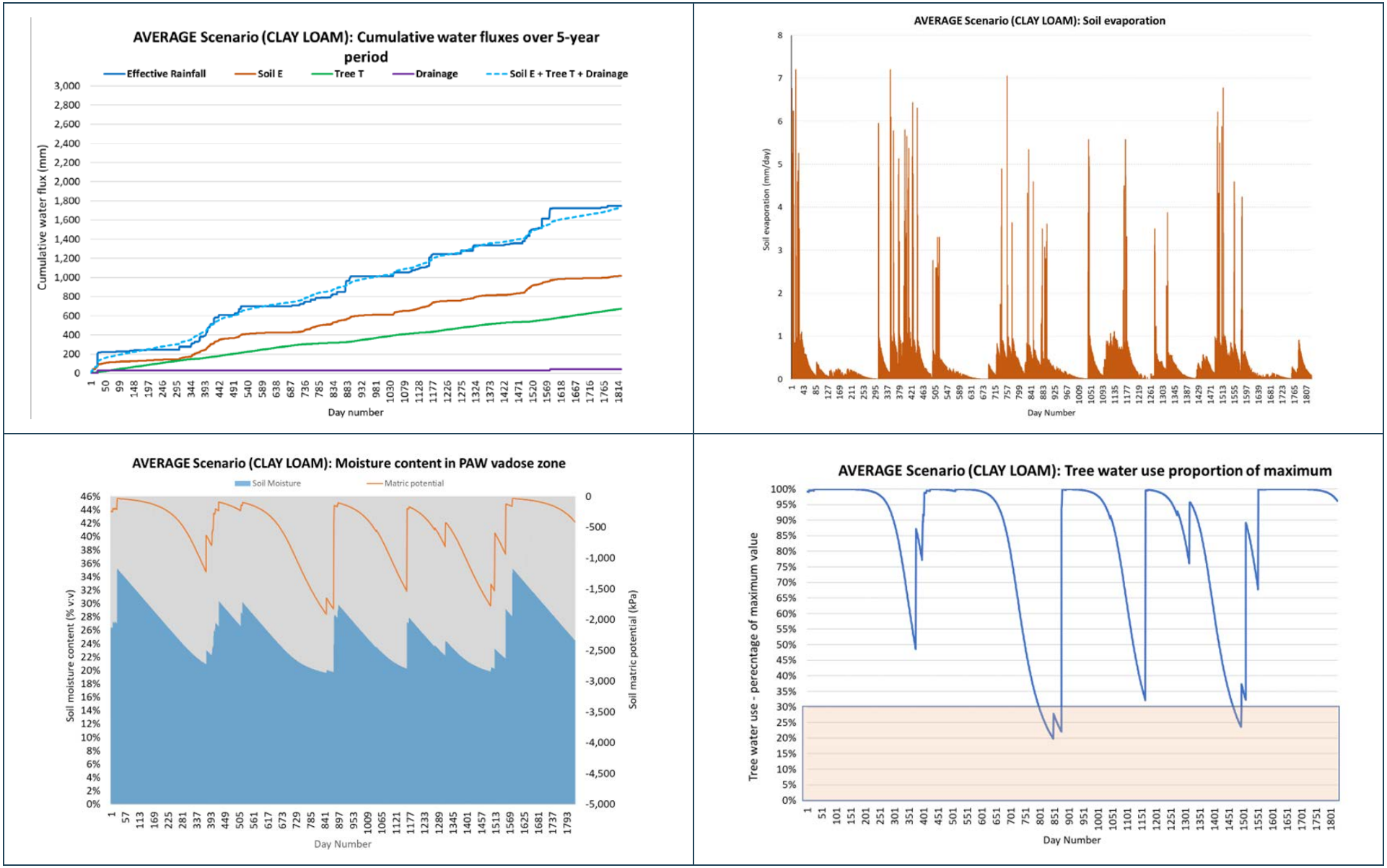


Figure 9.18 Summary of the Ecohydrological Water Balance Model Results – Average Climate

Table 9.7 Average climate ecohydrological characteristics – Fortescue Valley *Eucalyptus victrix* woodlands

Climate	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average	AGGREGATE RESULTS				
Transpiration function	Base Case	CURVE 1	CURVE 3	Base Case	CURVE 1	CURVE 3	Base Case	CURVE 1	CURVE 3	Base Case	CURVE 1	CURVE 3	Average climate				
Soil type	SANDY LOAM	SANDY LOAM	SANDY LOAM	SILT LOAM	SILT LOAM	SILT LOAM	CLAY LOAM	CLAY LOAM	CLAY LOAM	CLAY	CLAY	CLAY	3 x transpiration curves				
SBA	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4 x soil types				
Root Zone Depth (m)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0					
SUMMARY TABLE	mm/year	mm/year	mm/year	mm/year	mm/year	mm/year	mm/year	mm/year	mm/year	mm/year	mm/year	mm/year	mm/year	mm/year	mm/year	mm/year	mm/year
Effective rainfall	351	351	351	351	351	351	351	351	351	351	351	351	351	351	351	351	351 to 351
Soil Evaporation	-191	-191	-191	-201	-201	-201	-203	-203	-203	-201	-201	-201	-203	-199	-201	-191	-191 to -203
Tree water use	-138	-129	-139	-146	-139	-148	-135	-128	-136	-128	-121	-129	-148	-135	-136	-121	-121 to -148
Groundwater recharge	-20	-27	-19	-7	-7	-7	-8	-13	-6	-11	-15	-10	-27	-13	-11	-6	-6 to -27
Change in surface storage (+ve = input)	4.0	4.0	4.0	5.4	5.4	5.4	5.7	5.7	5.7	6.1	6.1	6.1	4.0	5.3	5.5	6.1	4 to 6
Change in tree PAW storage (+ve = input)	12.1	9.5	12.3	13.1	5.6	14.5	3.9	2.3	3.9	-1.0	-3.3	-1.0	-3.3	6.0	4.8	14.5	-3 to 14
DIFF (inputs - losses)	18.3	18.3	18.3	14.9	14.9	14.9	15.0	14.9	15.0	15.9	16.0	15.9	14.9	16.0	15.4	18.3	15 to 18
Water Balance ERROR	5.0%	5.0%	5.0%	4.0%	4.1%	4.0%	4.1%	4.2%	4.1%	4.5%	4.5%	4.5%	4.0%	4.4%	4.3%	5.0%	4.0% to 5.0%
GROSS Recharge to soil root zone	-146	-146	-146	-140	-140	-140	-139	-139	-139	-140	-140	-140	-146	-141	-140	-139	-139 to -146
NET Recharge to soil root zone	-126	-119	-127	-133	-133	-133	-131	-126	-132	-129	-124	-130	-133	-129	-129	-119	-119 to -133
Surface soil layer balance ERROR	*18.6*	*18.6*	*18.6*	*15.0*	*15.0*	*15.0*	*15.2*	*15.2*	*15.2*	*16.2*	*16.2*	*16.2*	*15.0*	*16.3*	*15.7*	*18.6*	*15 to 19*
PAW tree storage balance ERROR	*-0.3*	*-0.3*	*-0.3*	*-0.2*	*-0.2*	*-0.2*	*-0.3*	*-0.3*	*-0.3*	*-0.3*	*-0.3*	*-0.3*	*-0.3*	*-0.3*	*-0.3*	*-0.2*	*0 to 0*
IN	367	365	367	370	362	371	361	359	361	356	354	356	354	363	362	371	354 to 371
OUT	-349	-346	-349	-355	-347	-356	-346	-344	-346	-340	-338	-340	-356	-346	-346	-338	-338 to -356
DIFF	18	18	18	15	15	15	15	15	15	16	16	16	15	16	15	18	15 to 18
Total ET	-329	-320	-330	-348	-340	-349	-338	-331	-339	-329	-323	-331	-349	-334	-331	-320	-320 to -349
Groundwater recharge as % of rainfall	5.7%	7.6%	5.4%	2.0%	2.0%	2.0%	2.3%	3.7%	1.8%	3.2%	4.4%	2.8%	1.8%	3.6%	3.0%	7.6%	2.0% to 8.0%
Number of days of drought stress in period	91	0	50	2	0	0	106	0	5	187	44	68	0	46	25	187	0 to 187
Longest period where tree water use less than 30% of max	62	0	37	2	0	0	78	0	3	97	18	37	0	28	11	97	0 to 97
Longest period where tree water use less than 10% of max	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0 to 0

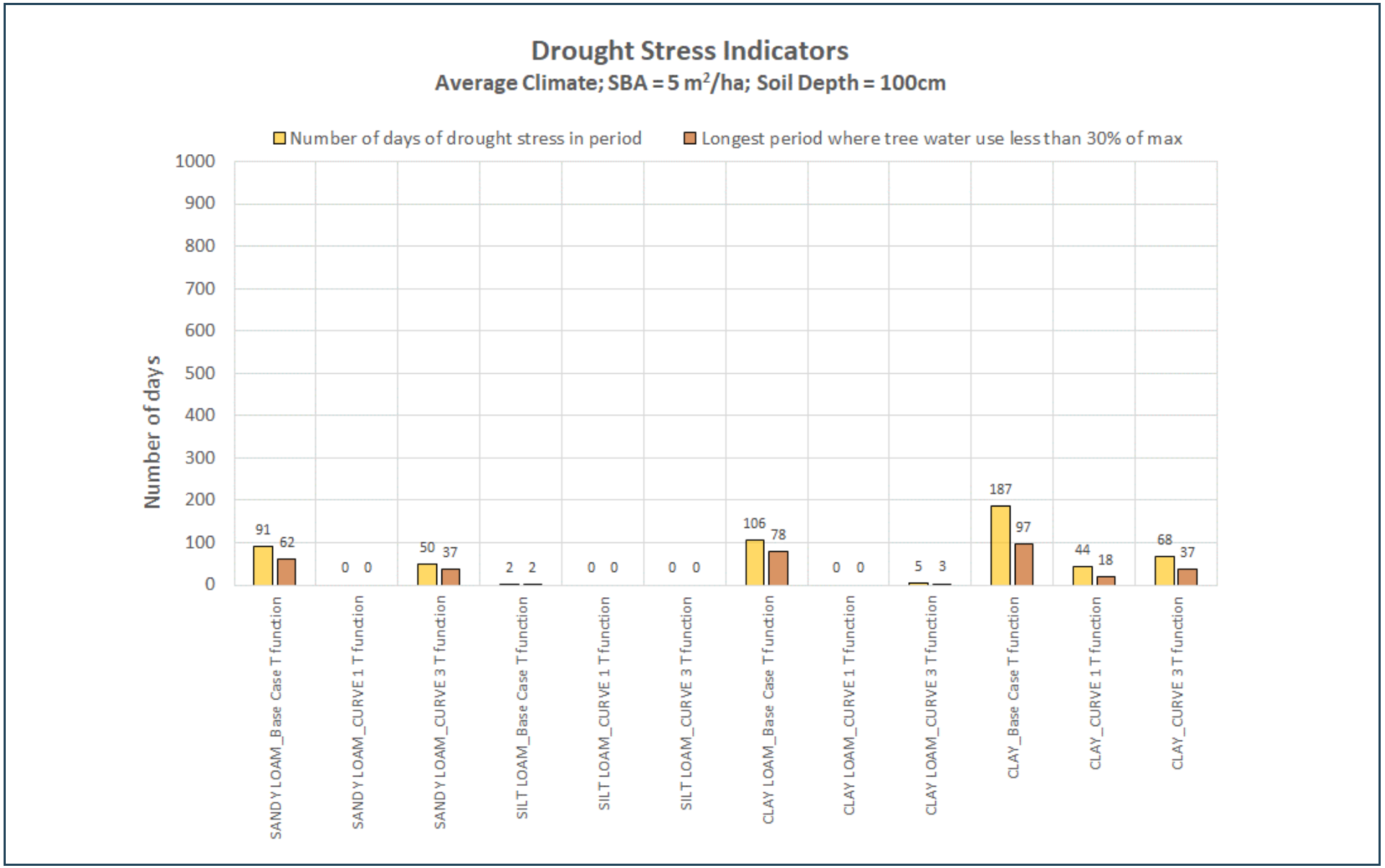


Figure 9.19 Aggregate Summary of Drought Stress Indicators – Average Climate

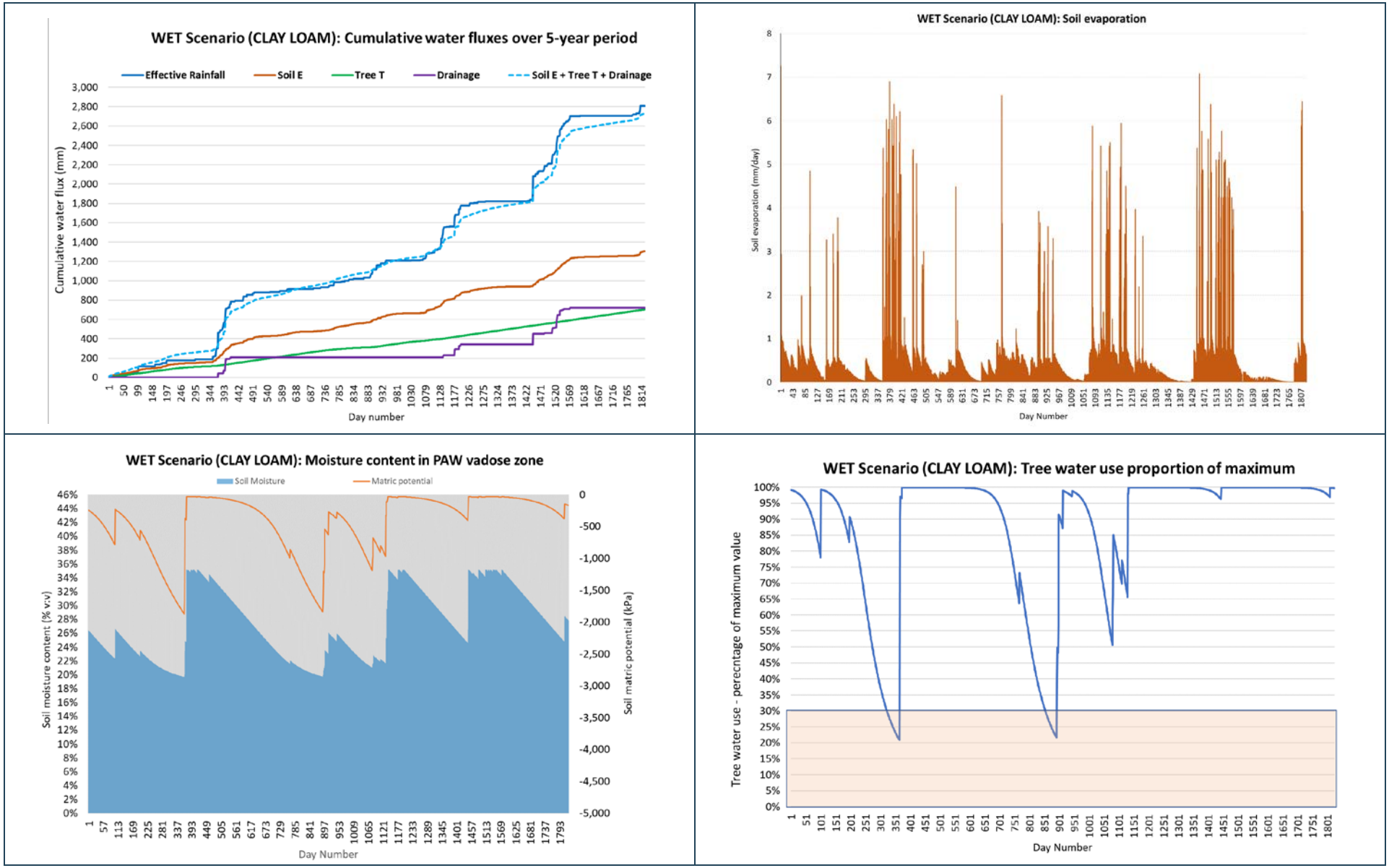


Figure 9.20 Summary of the Ecohydrological Water Balance Model Results – Wet Climate

Table 9.8 Wet Climate Ecohydrological Characteristics – Fortescue Valley *Eucalyptus victrix* woodlands

Climate	Wet	Wet	Wet	Wet	Wet	Wet	Wet	Wet	Wet	Wet	Wet	Wet	AGGREGATE RESULTS				
Transpiration as a function of soil matric potential	Base Case	CURVE 1	CURVE 3	Base Case	CURVE 1	CURVE 3	Base Case	CURVE 1	CURVE 3	Base Case	CURVE 1	CURVE 3	Wet climate				
Soil type	SANDY LOAM	SANDY LOAM	SANDY LOAM	SILT LOAM	SILT LOAM	SILT LOAM	CLAY LOAM	CLAY LOAM	CLAY LOAM	CLAY	CLAY	CLAY	3 x transpiration curves				
SBA	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4 x soil types				
Root Zone Depth (m)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0					
SUMMARY TABLE	mm/year	mm/year	mm/year	mm/year	mm/year	mm/year	mm/year	mm/year	mm/year	mm/year	mm/year	mm/year	mm/year	mm/year	mm/year	mm/year	mm/year
Effective rainfall	562	562	562	562	562	562	562	562	562	562	562	562	562	562	562	562	562 to 562
Soil Evaporation	-251	-251	-251	-259	-259	-259	-261	-261	-261	-257	-257	-257	-261	-257	-258	-251	-251 to -261
Tree water use	-146	-132	-148	-157	-145	-157	-141	-130	-143	-123	-113	-127	-157	-138	-142	-113	-113 to -157
GW recharge	-155	-167	-154	-130	-142	-130	-144	-154	-142	-160	-168	-156	-168	-150	-154	-130	-130 to -168
Change in surface storage (+ve = input)	3.3	3.3	3.3	3.7	3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.6	3.3	3.6	3.6	3.7	3 to 4
Change in tree PAW storage (+ve = input)	5.2	2.6	5.4	-2.0	-2.5	-2.0	-2.9	-4.5	-2.8	-7.2	-9.6	-7.2	-9.6	-2.3	-2.6	5.4	-10 to 5
DIFF (inputs - losses)	17.6	17.6	17.6	16.6	16.4	16.6	16.5	16.5	16.5	18.4	18.3	18.4	16.4	17.3	17.1	18.4	16 to 18
Water Balance ERROR	3.1%	3.1%	3.1%	3.0%	2.9%	3.0%	2.9%	2.9%	2.9%	3.3%	3.3%	3.3%	2.9%	3.1%	3.0%	3.3%	3.0% to 3.0%
GROSS Recharge to soil root zone	-293	-293	-293	-287	-287	-287	-285	-285	-285	-287	-287	-287	-293	-288	-287	-285	-285 to -293
NET Recharge to soil root zone	-138	-126	-139	-156	-145	-156	-141	-131	-143	-127	-119	-131	-156	-138	-139	-119	-119 to -156
Surface soil layer balance ERROR	*20.6*	*20.6*	*20.6*	*19.3*	*19.3*	*19.3*	*19.4*	*19.4*	*19.4*	*21.5*	*21.5*	*21.5*	*19.3*	*20.2*	*20.0*	*21.5*	*19 to 22*
PAW tree storage balance ERROR	*-3.0*	*-3.0*	*-3.0*	*-2.6*	*-2.9*	*-2.6*	*-2.9*	*-2.9*	*-2.9*	*-3.1*	*-3.2*	*-3.1*	*-3.2*	*-2.9*	*-2.9*	*-2.6*	*-3 to -3*
IN	570	568	570	563	563	563	562	561	563	558	556	558	556	563	563	570	556 to 570
OUT	-553	-550	-553	-547	-546	-547	-546	-544	-546	-540	-537	-540	-553	-546	-546	-537	-537 to -553
DIFF	18	18	18	17	16	17	16	17	16	18	18	18	16	17	17	18	16 to 18
Total ET	-397	-383	-399	-416	-405	-417	-402	-391	-404	-380	-369	-383	-417	-396	-398	-369	-369 to -417
GW recharge as % of rainfall	27.6%	29.7%	27.4%	23.2%	25.2%	23.2%	25.7%	27.4%	25.2%	28.4%	29.9%	27.8%	23.2%	26.7%	27.4%	29.9%	23.0% to 30.0%
Number of days of drought stress in period	55	9	26	0	0	0	83	9	0	272	274	144	0	73	18	274	0 to 274
Longest period where tree water use less than 30% of max	55	9	26	0	0	0	44	9	0	111	101	73	0	36	18	111	0 to 111
Longest period where tree water use less than 10% of max	0	0	0	0	0	0	0	0	0	0	0	0					

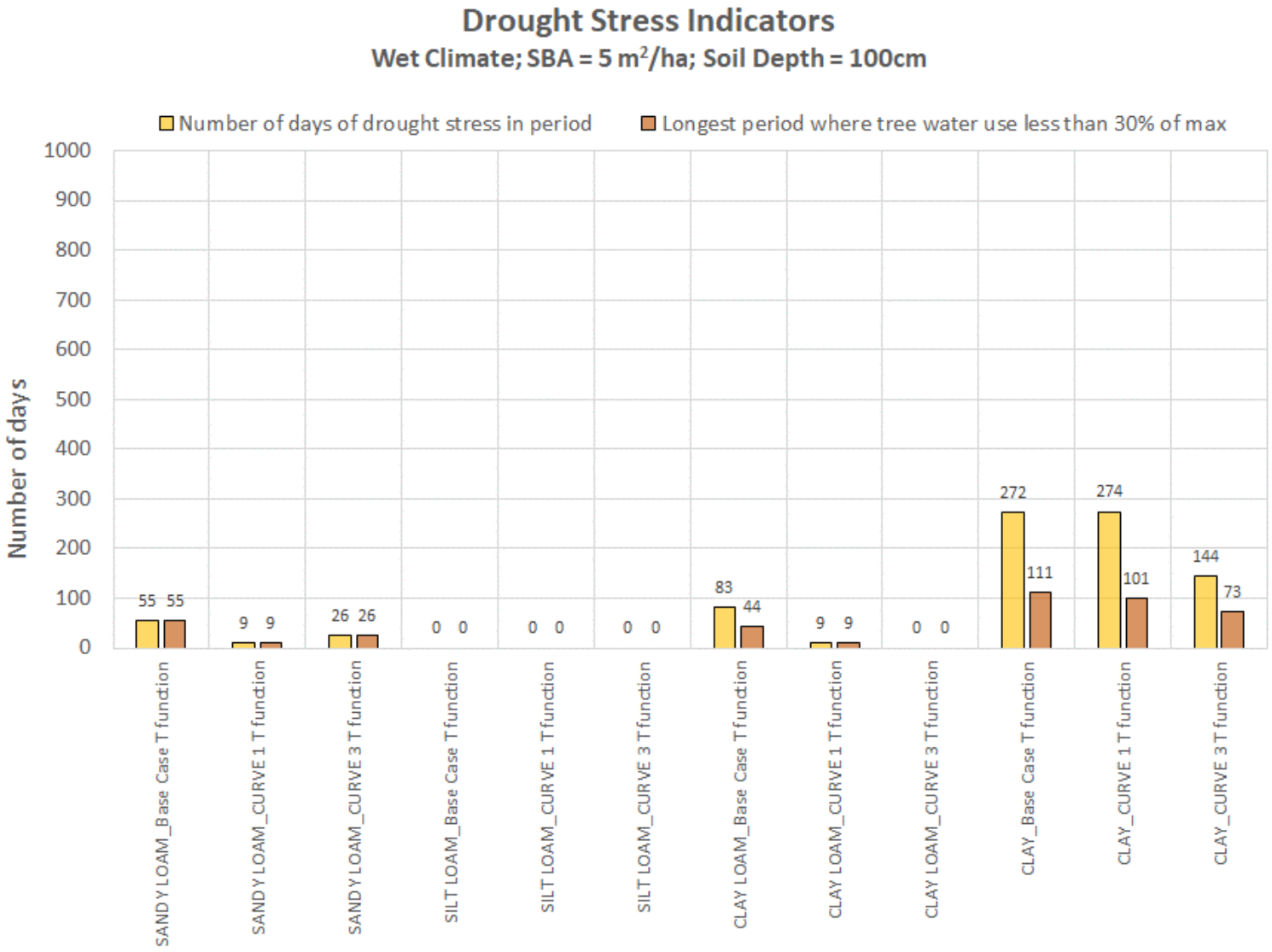


Figure 9.21 Aggregate Summary of Drought Stress Indicators – Wet Climate

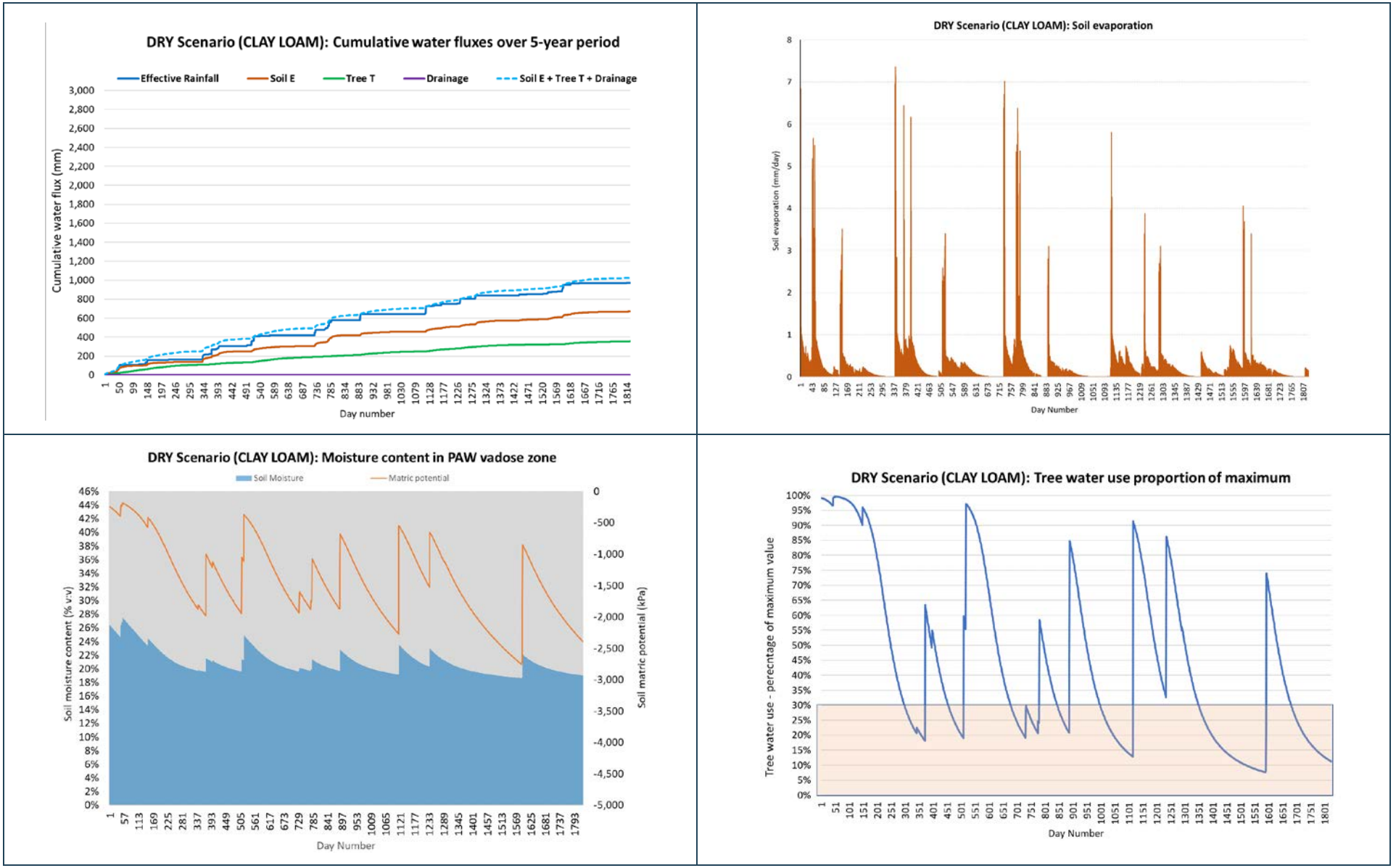


Figure 9.22 Summary of the Ecohydrological Water Balance Model Results – Dry Climate

Table 9.9 Dry Climate Ecohydrological Characteristics – Fortescue Valley *Eucalyptus victrix* woodlands

Climate	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
Transpiration as a function of soil matric potential	Base Case	CURVE 1	CURVE 3	Base Case	CURVE 1	CURVE 3	Base Case	CURVE 1	CURVE 3	Base Case	CURVE 1	CURVE 3
Soil type	SANDY LOAM	SANDY LOAM	SANDY LOAM	SILT LOAM	SILT LOAM	SILT LOAM	CLAY LOAM	CLAY LOAM	CLAY LOAM	CLAY	CLAY	CLAY
SBA	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Root Zone Depth (m)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

AGGREGATE RESULTS
Dry climate
3 x transpiration curves
4 x soil types

SUMMARY TABLE	mm/year	mm/year	mm/year	mm/year	mm/year	mm/year	mm/year	mm/year	mm/year	mm/year	mm/year	mm/year	mm/year	mm/year	mm/year	mm/year	mm/year
Effective rainfall	195	195	195	195	195	195	195	195	195	195	195	195	195	195	195	195	195 to 195
Soil Evaporation	-117	-117	-117	-131	-131	-131	-134	-134	-134	-136	-136	-136	-136	-129	-132	-117	-117 to -136
Tree water use	-90	-88	-91	-86	-83	-88	-71	-69	-74	-59	-57	-61	-91	-76	-78	-57	-57 to -91
GW recharge	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0 to 0
Change in surface storage (+ve = input)	3.7	3.7	3.7	5.1	5.1	5.1	5.5	5.5	5.5	6.0	6.0	6.0	3.7	5.1	5.3	6.0	4 to 6
Change in tree PAW storage (+ve = input)	20.1	18.3	21.5	26.6	24.3	29.1	14.8	12.6	17.1	4.0	2.1	6.1	2.1	16.4	17.7	29.1	2 to 29
DIFF (inputs - losses)	11.3	11.3	11.3	9.8	9.8	9.8	9.4	9.4	9.4	9.7	9.7	9.7	9.4	10.0	9.8	11.3	9 to 11
Water Balance ERROR	5.2%	5.2%	5.1%	4.3%	4.4%	4.3%	4.4%	4.4%	4.3%	4.8%	4.8%	4.7%	4.3%	4.7%	4.6%	5.2%	4.0% to 5.0%
GROSS Recharge to soil root zone	-70	-70	-70	-59	-59	-59	-57	-57	-57	-55	-55	-55	-70	-60	-58	-55	-55 to -70
NET Recharge to soil root zone	-70	-70	-70	-59	-59	-59	-57	-57	-57	-55	-55	-55	-70	-60	-58	-55	-55 to -70
Surface soil layer balance ERROR	*11.3*	*11.3*	*11.3*	*9.8*	*9.8*	*9.8*	*9.4*	*9.4*	*9.4*	*9.7*	*9.7*	*9.7*	*9.4*	*10.1*	*9.8*	*11.3*	*9 to 11*
PAW tree storage balance ERROR	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0 to 0*
IN	218	217	220	226	224	229	215	213	217	205	203	207	203	216	217	229	203 to 229
OUT	-207	-205	-208	-216	-214	-219	-205	-203	-208	-195	-193	-197	-219	-206	-206	-193	-193 to -219
DIFF	11	11	11	10	10	10	9	9	9	10	10	10	9	10	10	11	9 to 11
Total ET	-207	-205	-208	-216	-214	-219	-205	-203	-208	-195	-193	-197	-219	-206	-206	-193	-193 to -219
GW recharge as % of rainfall	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0% to 0.0%
Number of days of drought stress in period	568	306	458	569	361	432	779	539	595	921	803	781	306	593	569	921	306 to 921
Longest period where tree water use less than 30% of max	212	149	191	227	179	204	242	205	221	256	226	237	149	212	217	256	149 to 256
Longest period where tree water use less than 10% of max	95	28	114	47	5	76	72	47	93	103	87	118	5	74	82	118	5 to 118

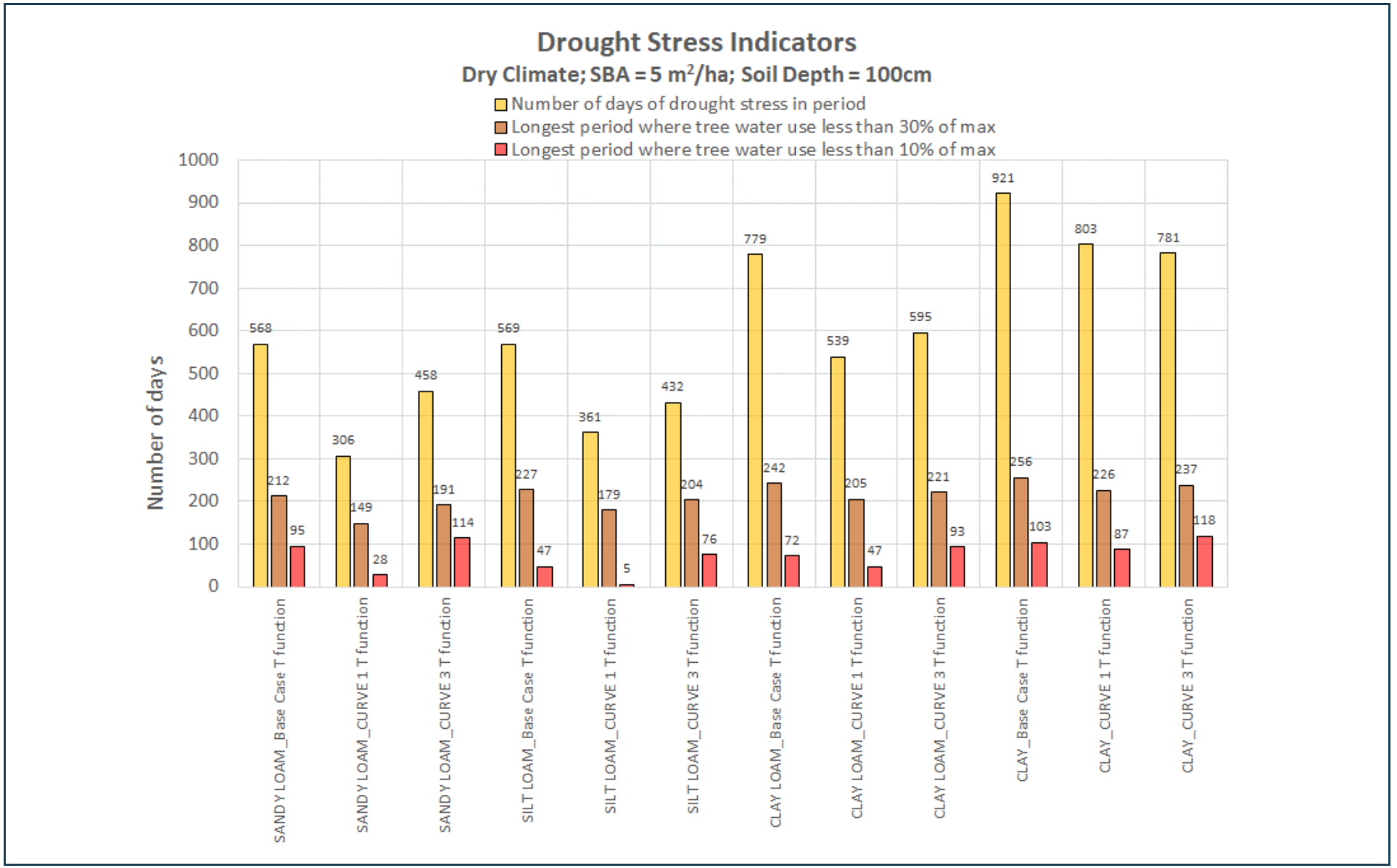


Figure 9.23 Aggregate Summary of Drought Stress Indicators – Dry Climate

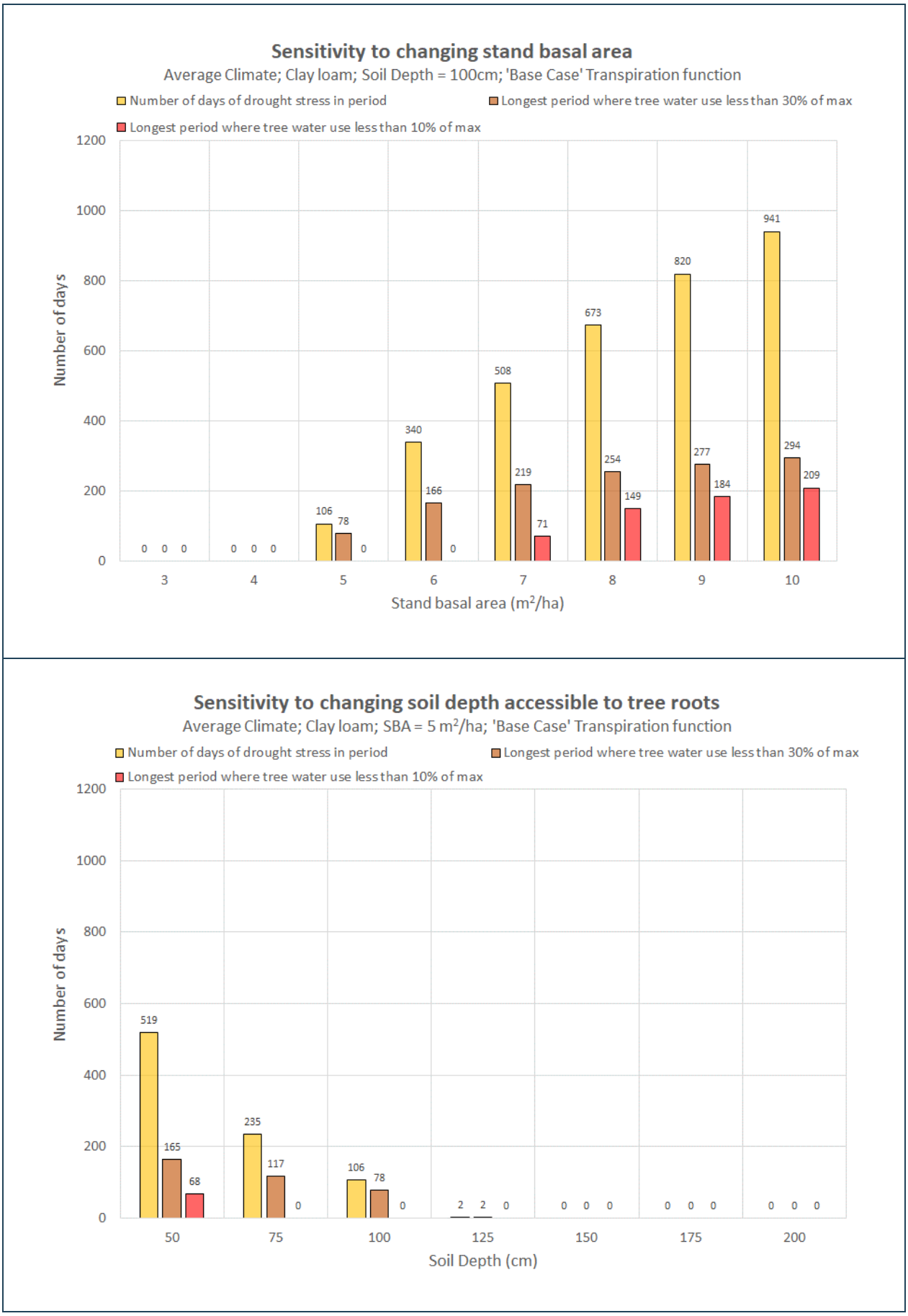


Figure 9.24 Average Climate - Sensitivity to Changing Stand Basal Area (top) and Soil Profile Depth (bottom)

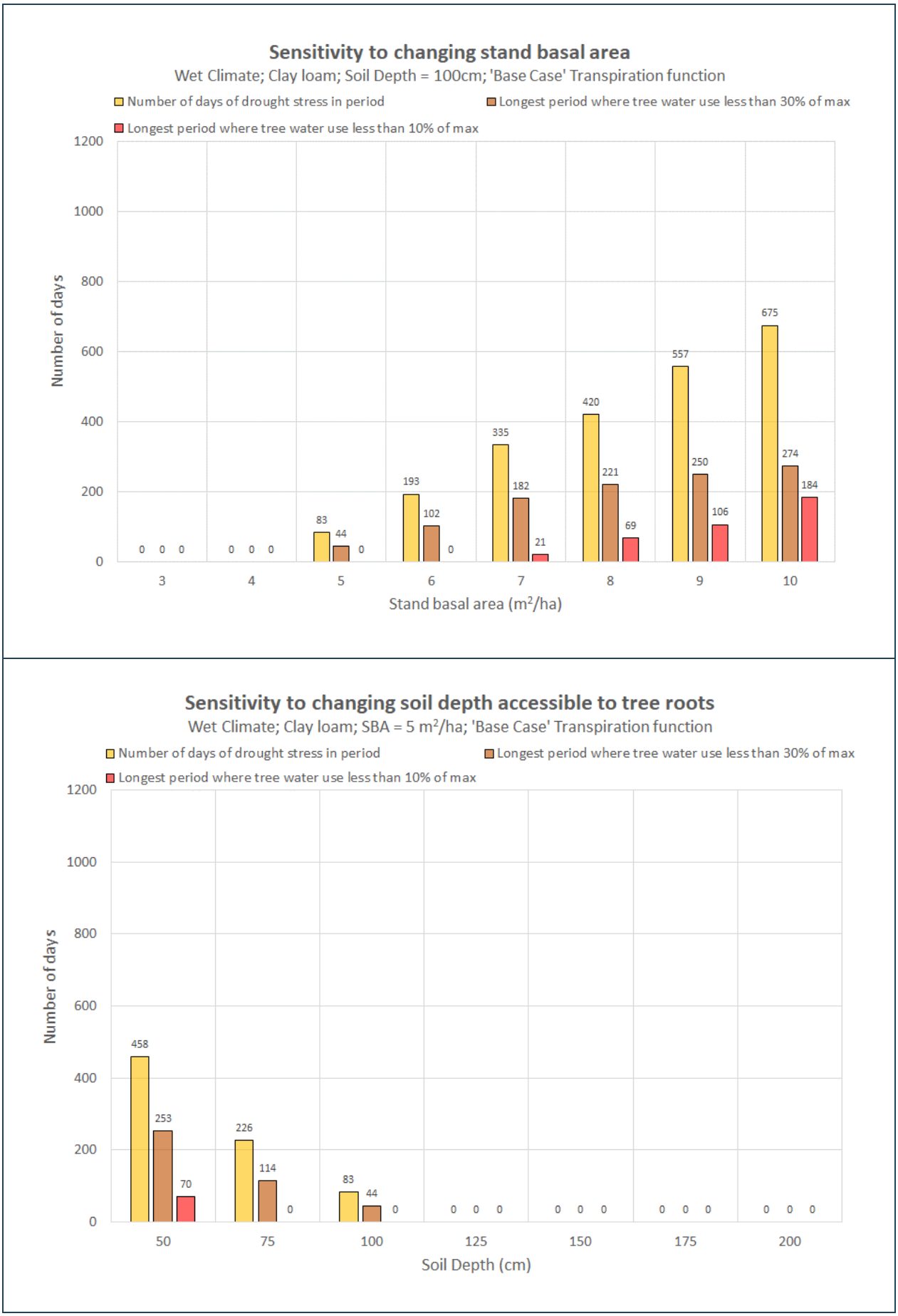


Figure 9.25 Wet Climate - Sensitivity to Changing Stand Basal Area (top) and Soil Profile Depth (bottom)

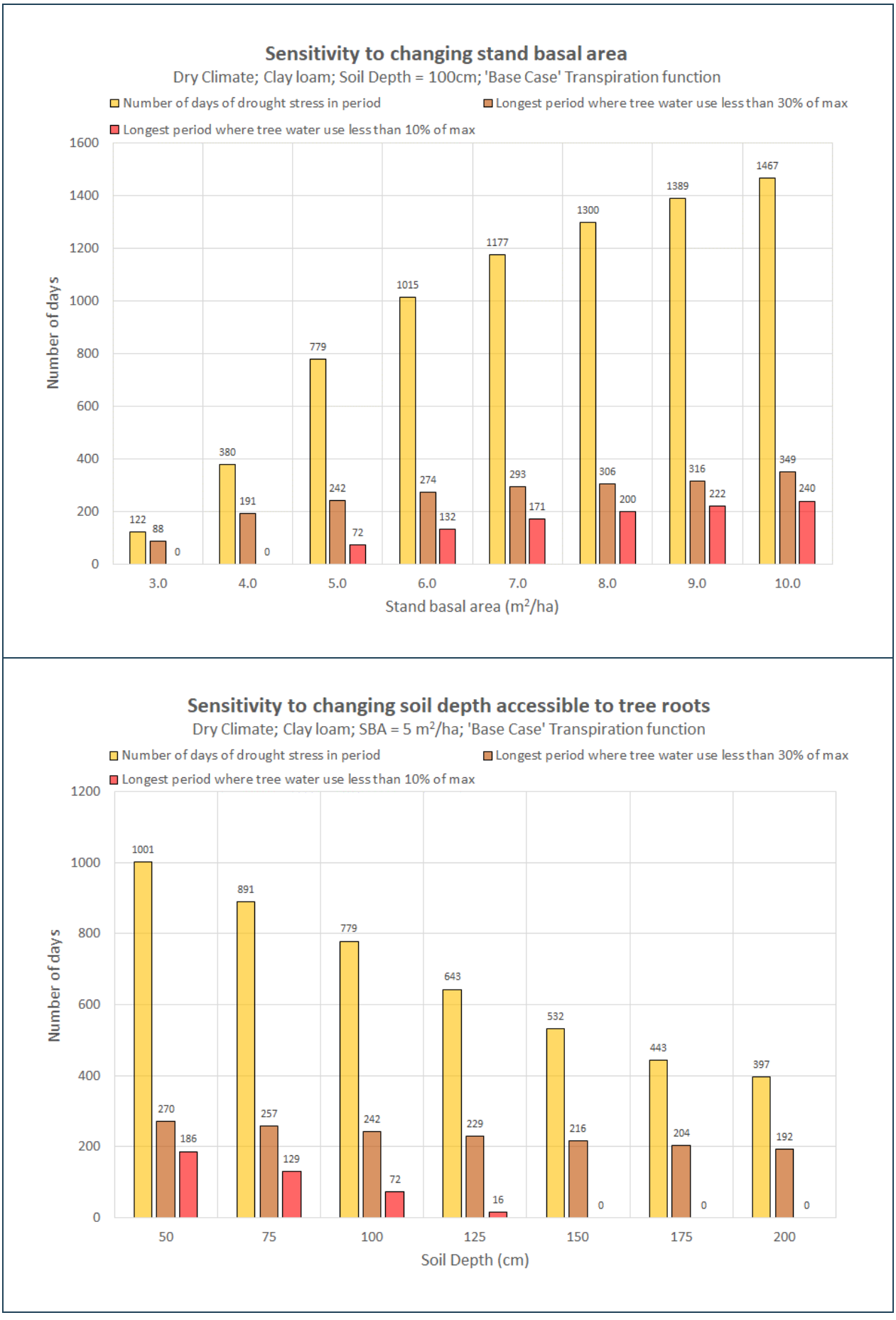


Figure 9.26 Dry Climate - Sensitivity to Changing Stand Basal Area (top) and Soil Profile Depth (bottom)

9.7.4 Ecohydrological Baseline for Fortescue Valley E. victrix woodlands

The results of the EWB modelling scenarios and sensitivity analysis support the contention that *E. victrix* trees in the open woodland/woodland formations of the Fortescue Valley are not phreatophytic. Based on these results in combination with the completed field data collection, the postulated natural (i.e. pre-disturbance) baseline is summarised as follows:

- The *E. victrix* woodlands occur in relatively tree low density, open formations across landscape units of the Fortescue Valley (SBA range = 2-10 m^2/ha in patches; with broader landscape SBA of about 3- 5 m^2/ha). Inter-patch variation is attributable to heterogeneity in soil depth, texture and terrain characteristics affecting the capture and infiltration of surface inflows from upgradient areas. Woodland stands with SBA > 7 m^2/ha are more likely to rely on surface inflows to augment direct rainfall. In the lowest depressions, prolonged waterlogging may ultimately constitute a constraint to woodland persistence.
- The woodland structure is dominated by large, mature trees. Recruitment occurs episodically during wet climate phases; however, recruitment efficacy (i.e. percentage conversion of seedlings into mature trees) is low, as the young trees succumb to drought stress exacerbated by competition with mature trees and understorey grasses where present. Other mortality factors such as herbivory by insects and cattle may also be relevant and interactive with drought stress. Observations of this dynamic for *E. victrix* has been reported in the Upper Fortescue Valley by Fox et al. (2004) and it is considered the same applies to the woodlands of the lower Fortescue Valley. Successful recruitment is presumably constrained to infrequent 'multi-year windows' involving a succession of favourable climatic conditions.
- Tree root systems are relatively shallow, owing to subsoil constraints include calcrete sheeting and/or dense, high bulk density clay that is prone to waterlogging. However, the root systems are laterally expansive and extend well beyond the tree canopy radius. This root system morphology is commonly observed in *E. victrix* growing in Pilbara riparian environments but has not been directly investigated in the *E. victrix* woodlands of the Study Area.
- The woodland trees are regularly exposed to drought stress and have various drought tolerance adaptations. Prevalent water use regulation (i.e. stomatal closure) is indicated by suppressed stem growth rates. The leaf area index (LAI) of the woodland stands fluctuates through time in response to soil moisture. Adjustments to reduced soil moisture include leaf shedding, limb dropping and under more extreme conditions selective tree deaths (self-thinning). Adjustments to increased soil moisture include leaf growth flushes and seedling recruitment. The likely range of SBA fluctuation associated with these processes is circa ±30%.
- Vadose zone soil water replenishment is facilitated by infiltrated rainfall, with augmentation by surface inflows in areas, as dictated by catchment hydrology. Most rainfall is consumed by ET consistent with the Budyko model (Section 3.2). At the landscape scale, the transpiration flux of woodland trees is in the order of 100 to 150 mm/year during more favourable climate sequences and 50 to 100 mm/year during drier sequences. Soil and understorey evaporation generally account for the balance of rainfall, with the ratio of T/ET being in the order of 30 to 40%. In areas where PAW is augmented by inundation, then evaporation will also occur directly from standing water bodies. Given the fine grained soils which result in low rates of infiltration, evaporation is likely to be the primary discharge from the claypan water bodies. The EWB modelled soil evaporation rates are consistent with actual measurements in the central Pilbara by Tugwell-Wootton et al. (2020). Groundwater recharge is restricted to infrequent large downpours and floods.

9.7.5 Key Assumptions, Limitations and Uncertainties

Natural systems are inherently complex, with multiple interacting processes operating across different ecosystem scales (e.g. stand level, individual trees, individual branches/leaves, plant cells). All ecosystem models necessarily involve simplifications of these complex elements and processes. Well-designed

ecohydrological models have a sound conceptual basis, are targeted to specific questions, and capture key elements and processes at scales that are relevant to the driving questions. It is also important that the mathematical formulation of models, and the scientific theories that underpin them, are suitably transparent and understandable to the target audience (Tague and Frew 2020).

The EWB Model is a 'bucket type' water balance model that has been parsimoniously developed to capture key processes in the *E. victrix* woodland ecosystems of the Fortescue Valley, to provide insights into the role of vadose storage in meeting the ecological water requirements of the woodland trees. The principal water balance inputs and outputs used in the EWB model are necessarily based on plausible upper and lower bounds, selected using the best available information. This comprises a combination of field observations, measurements and more general scientific theories and extrapolations from studies in similar environments.

Key limitations and uncertainties of the EWB Model, and approaches taken to address these, are discussed as follows:

- The EWB is effectively a 1D vertical model, with no lateral inputs or outputs. Therefore, soil water recharge is solely derived from direct rainfall. In reality, surface water lateral redistribution processes do operate in the valley woodlands of the Study Area, with the most important being inflows and the formation of transient waterbodies in the claypans. On this basis, the assumption of no lateral inputs or outputs is conservative (i.e. soil water inputs from surface inflows are underestimated). This assumption is therefore appropriate with respect to identifying if groundwater is an important vegetation water source.
- The modelled soil profile is a simple, uniform layer (i.e. no allowance for spatial heterogeneity). Soil profile depth and texture has been inferred from a limited set of observations in the Fortescue Valley, but not directly measured at locations where tree measurements were made. Note that direct observation is subject to access constraints in the Gnalka Gnoona and Koodjeepindarranna Claypan environs. Similarly, no direct measurement of soil evaporation, soil infiltration and soil water replenishment dynamics in the Study Area have been completed; however, time series leaf water potential measurements between 20019 and 2022 provide some indication of the variation in soil moisture experienced by tree roots. The EWB incorporates a sensitivity analysis addressing these aspects.
- Simplistic assumptions have been made regarding the calcrete layers beneath the overlying soil profile. In reality the calcrete may be highly heterogenous vertically and laterally. In some areas it is likely that tree roots can penetrate into the weathered calcrete to some degree, which may provide a degree of PAW storage including transient perching lenses above the water table. Percolation behaviour through the calcrete may also be complex. Notwithstanding these aspects, the assumption that the calcrete does not contribute to PAW and separates the trees from the valley groundwater is conservative and therefore appropriate with respect to identifying if groundwater is an important vegetation water source.
- *E. victrix* root systems are assumed to be laterally extensive and achieve 'full soil profile occupancy' across the model domain. This assumption is considered to be reasonable on the basis of knowledge of *E. victrix* root morphology in the Pilbara, and arid zone woodland trees more generally (Tumber-Davila et al. 2022); notwithstanding that it may be less appropriate at the low end of modelled tree density/SBA. In the EWB Model, root zone occupancy effectively impacts the volumetric storage that is available to the trees. As such, variability of this parameter is indirectly addressed by the soil depth and texture sensitivity analyses.

- The relationship between SBA and transpiration flux is based on long-term, upper and lower bounds of mean tree water use for *E. victrix* in the Pilbara region and is also consistent with the Budyko model for the Study Area. Similarly, functions relating transpiration flux to soil moisture content are consistent with typical relationships across multiple tree species. However, direct measurements of *E. victrix* water use in the Fortescue Valley have not been undertaken and therefore these inferred relationships have not been validated. The EWB incorporates a sensitivity analysis addressing these aspects. The measured SBA plots include direct measurement of tree mortality (refer Section 9.4.2) that are consistent with a pattern of cyclic SBA/LAI adjustment at the stand scale.
- Groundwater recharge is modelled as a uniform flux through the base of the vadose zone occupied by tree roots, with 100% transfer through the separating calcrete layer. Percolation to the groundwater system only occurs when the entirety of the vadose layer reaches field capacity. No account has been made for preferred pathway flow that could bypass the PAW storage layer, thereby reducing volumes available for uptake by trees. However, the notion of impeded percolation in the valley sediments is consistent with the preponderance of fine textured soils and bore hydrograph data from the Study Area. The approach taken is parsimonious given the limited information about the regolith overlying the water table. The importance of preferred pathway flows principally relates to the replenishment of volumetric storage of PAW. As such, to some extent this aspect is indirectly addressed by the soil depth and texture sensitivity analyses.
- By virtue of the spatial layout of the monitoring bore network, which is subject to logistical and access constraints, groundwater levels have not been directly measured at the tree measurement locations. Consequently, the depth to the water table has been inferred to be > 4 mbgl using data from the nearest available bores. Possible finer resolution and/or site-specific aspects (e.g. whether there is a lens of fresher groundwater overlying the brackish/saline water body) cannot be measured. This has been partially addressed by assuming the tree roots are confined to the upper 200 cm of the soil profile under all modelling scenarios, which is well above the zone of potential capillary rise based on the valley sediment hydraulic properties.
- Drought severity has been inferred using drought stress indicators linked to cumulative exposure to dry soil conditions, in the absence of quantitative deterministic relationships for *E. victrix* based on soil moisture content (for example such as those presented in Figure 9.17). However, given the level of uncertainty in estimating soil water content across the model domain, this is not considered to be materially important for interpreting the model results.
- It is assumed that the zone of tree root occupation is relatively well drained, precluding potential effects of seasonal or prolonged waterlogging. This is predicated on the assumption that *E. victrix* tree roots cannot tolerate extended periods of waterlogging, as has been documented in Pilbara riparian settings and glasshouse experiments (e.g. Argus 2018), with such areas being unoccupied by woodland vegetation as is the case in claypans adjacent to the woodland stands. In reality, occasional exposure to waterlogging occurs in the Fortescue Valley environs, and *E. victrix* is known to have a degree of tolerance to periodic waterlogging (Argus 2018, Florentine and Fox 2002). Notwithstanding, the dynamics of waterlogging is not considered to be a key process for identifying if groundwater is an important vegetation water source.
- The potential role of salinity in plant water uptake dynamics has not been considered. Soil salinity would be expected to accumulate in the valley soils in between flushing events. However, the limited available information suggests that flushing of surface soils layers is effective at preventing significant salt accumulation in *E. victrix* woodland stands. In general terms, at modest concentrations soil salinity increases the total matric potential of soil water thereby effectively shifting the soil water retention curve (reduced PAW for a given volumetric soil water content). As such, it is indirectly addressed by the soil depth and texture sensitivity analyses. Furthermore, taking into account the salinity of the valley groundwater system (TDS >4,000 mg/L), which reduces its suitability as a vegetation water source, salinity dynamics are not considered to be a key process for identifying if groundwater is an important vegetation water source.

10. CONCEPTUAL LANDSCAPE MODEL

10.1 Context

A series of landscape EHUs have been identified and spatially delineated for the Study Area and surrounds. Key elements and functional behaviours for each EHU have been determined to develop a landscape ecohydrological conceptual model for the Study Area (refer Section 8).

As outlined in Section 1, the Fortescue Valley in the vicinity of the Study Area (i.e. Mungurrdu) comprises the Gnalka Gnoona and Koodjeepindarranna Claypans, persistent pools and *E. victrix* woodland communities (that collectively provide a variety of habitats). As such, much of the following landscape conceptual model is focused on the ecohydrological characteristics of these wetlands. A plan of the estimated maximum potential catchment areas for each of the claypans is shown in Figure 3.2. Based on the findings from the surface water data assessment (Section 4) the effective catchment areas for the claypans (both temporally and spatially) are likely to be considerably smaller than the maximum potential catchment areas, as shown in Figure 4.6.

10.2 Geomorphology

The Koodjeepindarranna and Gnalka Gnoona Claypans appear to have developed as a result of geomorphological influences on the surface water drainage (refer Figure 10.1). From aerial images and geological mapping, it can be seen that, to the east and west of the claypans, the main drainage channel is located on the northern side of the Fortescue Valley, to the north of the outcropping calcrete. In the vicinity of the claypans, this flow path is interrupted by alluvial fans from both the northern and southern sides of the Fortescue Valley. The encroachment of the northern and southern fans across the Valley floor, to the west of the Koodjeepindarranna Claypan, has resulted in a geomorphological / topographical barrier to surface water flow and the ponding of surface water to the east; the settlement of fines from the ponded water then forming the current claypan. Similarly, it appears that the alluvial fan between the Koodjeepindarranna and Gnalka Gnoona Claypans restricts surface water flow along the northern side of the Valley. However, in this area, there is the additional influence of outcropping calcrete which effectively "captures" surface water into a restricted pool, forming the Gnalka Gnoona Claypan.

The outcropping calcrete to the east of the Gnalka Gnoona Claypan also restricts the surface water flow off the Chichester Range, resulting in an area of ponding between the proposed mining area and the outcropping calcrete (refer Figure 10.1).

10.3 Fortescue Valley Soils and Woodlands

The Fortescue Valley soils are fine textured, alkaline and variably saline as influenced by flushing and evapo-concentration processes. The extensive woodlands of the Fortescue Valley occur on deeper, loamy surfaced soils (i.e. Sandy Clay Loam to Loamy Clay surface horizons) which typically overlie calcrete at 50 to 100 cm depth. The dominant overstorey species is *E. victrix*, generally occurring in association with *A. distans*. In valley depressions most prone to salinity and waterlogging, *A. stenophylla* and lignum (*Duma florulenta*) are prominent species.

E. victrix roots are laterally expansive in the Sandy Clay Loam to Loamy Clay surface horizons. However, massive calcrete or low permeability clay impedes vertical root penetration. In addition to comprising a physical barrier, the low permeability clay contributes to prolonged subsoil waterlogging following large replenishment events. The non-vegetated claypans are formed in the lowest depressions, with high clay content of surface soils contributing to restricted infiltration and waterbody formation following inflow events.

Taking into account the gradational soil texture (i.e. becoming finer textured with depth), the maximum vadose-zone storage of plant available water (PAW) (i.e. following drainage to field capacity) is

approximately 100 to 150 mm/m vertical depth.

E. victrix trees comprise the majority of SBA and leaf area index in the woodland vegetation communities. Overall, the stand basal area (SBA) of the woodland trees ranges between about 3 and 6 m^2/ha; which is low compared with other Pilbara ecotones (e.g. SBA > 10 m^2/ha is commonly observed in riparian woodlands of major rivers in the Central Pilbara).

By application of known relationships between tree size and water use (e.g. Zeppel 2013; Pfautsch et al. 2011, 2014), soil water depletion by transpiration of the Fortescue Valley *E. victrix* woodlands is estimated to be 50 to 130 mm/year; with a positive correlation between SBA and transpiration flux.

10.4 Fortescue Valley Drainage

The Project is located on the northern flanks of the Fortescue Valley and is fully contained within the Goodiadarrie Swamp sub-catchment, which has a total area of approximately 4,138 km^2 (HPPL 2013), with the swamp located on the northern side of the base of the valley and immediately to the south of the Project. The Goodiadarrie Swamp catchment is bounded by the Chichester Range to the north and the Hamersley Range to the south. Runoff from smaller rainfall events is likely to be contained within the Goodiadarrie Swamp area, with discharge into the Lower Fortescue River likely to require large rainfall events.

There are no permanent pools in the Study Area, indicating that that there is no surface expression of groundwater. However, a few persistent surface water fed pools have been identified (refer Figure 1.6). These small pools form in the depressions of disjunct, clay lined channels.

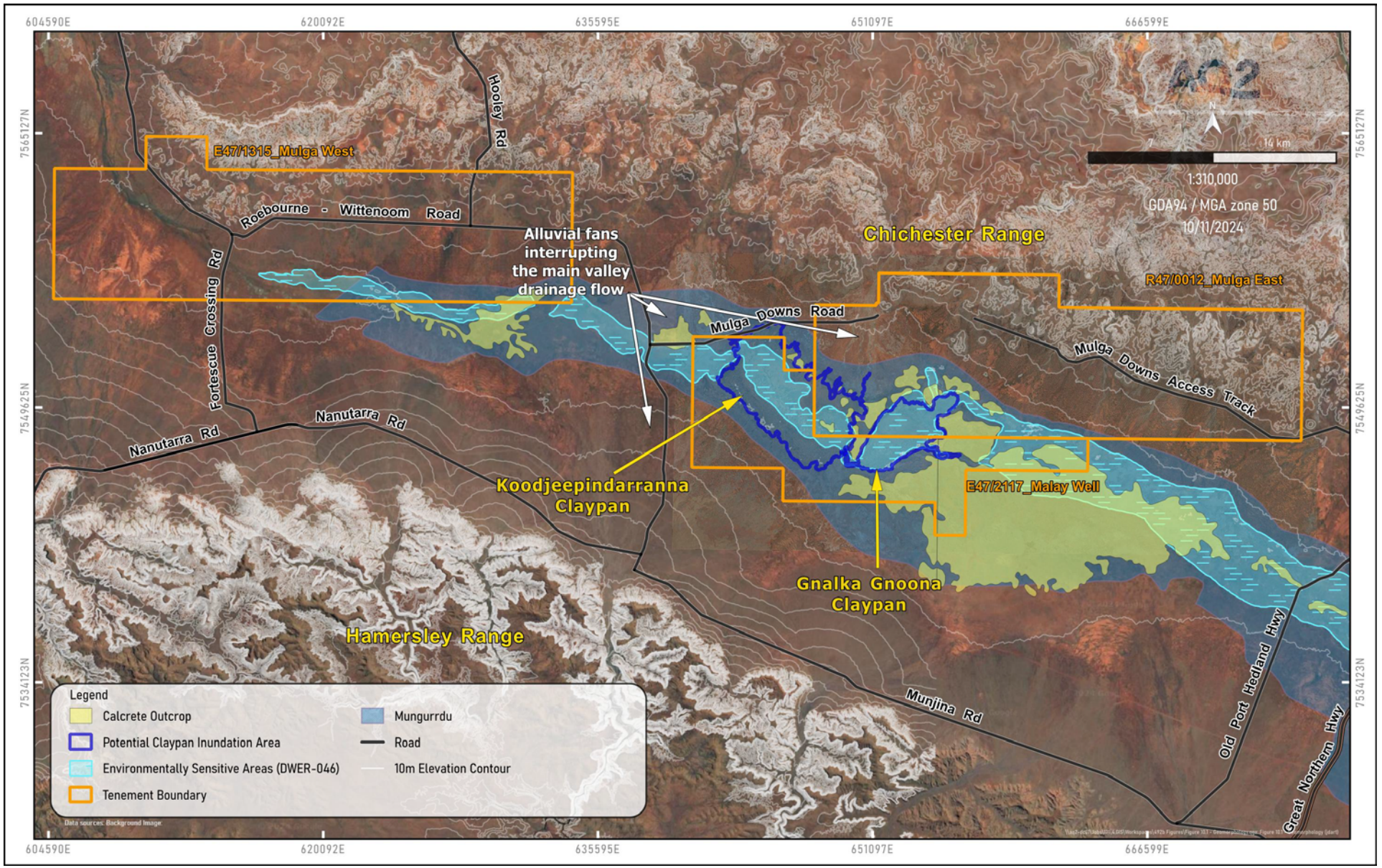


Figure 10.1 Geomorphology

10.5 Chichester and Hamersley Range Drainage Lines

The Koodjeepindarranna and Gnalka Gnoona Claypans have catchments that drain from both the north (Chichester Range) and the south (Hamersley Range) reporting to them, with the Project development area confined to the Chichester catchments. The larger drainage lines from the Chichester (and Hamersley) Range tend to form an alluvial fan where they reach the valley and the drainage lines become braided where they flow across their alluvial fans. However, there often appears to be a preferred drainage channel across each fan for flows from smaller, frequent runoff events. This means there are multiple discharge points from these catchments that contribute to a complex wetland mosaic in the Fortescue Valley.

Note that the eastern side of the Hamersley Range is flanked by the Rio Tinto Iron Ore rail line and the Nanutarra – Munjina Road which may modify runoff behaviour from this side of the catchment.

The surface water data assessment has identified that initial rainfall losses of 35 mm are required to be overcome before local runoff will occur (Section 4.3), with greater initial rainfall losses required for water to be collected within the claypans (90 mm from Chichester catchments and 120 mm from Valley catchments).

10.6 Claypans Overview

Runoff from the mine site area discharges to the Koodjeepindarranna Claypan and Gnalka Gnoona Claypan (Priority 1 PECs). The two claypans are hydraulically linked, with a flow channel between the claypans appearing to be activated when water levels in the Gnalka Gnoona Claypan exceed 402.9 mRL based on provided DEM data.

The potential maximum surface water catchment areas for the Gnalka Gnoona and Koodjeepindarranna Claypans (Figure 3.2) have been estimated to be approximately 1,857 km^2 in total. However, for most rainfall events, surface water inflows to the claypans are likely to be restricted to predominantly runoff from the Chichester Range catchments, localised catchments within the Fortescue Valley and from the Hamersley Range. The catchment areas are difficult to define, with contributions from different catchments likely to change depending on the size of the rainfall event. Catchment definition is also complicated by the behaviour of drainage lines across the alluvial fan, and the lack of defined drainage, localised ponding areas and calcrete outcropping within the floor of the Fortescue Valley. Preferential drainage paths identified in the 2D flood modelling completed for the broader surface water system assisted in defining the effective catchment areas draining to the claypans following widespread rainfall events. The assumptions on the effective catchment areas reporting to the claypans are discussed in Section 4, with effective total catchment areas of 817 km^2 (Koodjeepindarranna) and 215 km^2 (Gnalka Gnoona) assumed in the modelling.

After larger rainfall events, flow from the east through the Fortescue Valley (but restricted to the western side of the Goodiadarrie Hills) may also contribute to the claypans, and preferential flow channels within the alluvial fan are likely to overtop and cause water to discharge to other areas.

Inundation within the claypans appears to be frequent, based on the claypan water balance assessment completed and supported by findings made by Pinder et al. (2017) and Google Earth and LandSat images. Pinder et al. (2017) postulated that inundation can be persistent, indicating surface water may have been continuously present at Gnalka Gnoona Claypan for 3.5 years in the period 2003 to 2006. Review of Landsat 4-5 satellite imagery during this period, indicated prolonged ponding within the claypans is unlikely to occur and the claypans are thought to generally dry out each dry season (noting the period through the early 2000's was wetter than average). Further, the depth of water in the claypans to the invert of the downstream overflow point is estimated to be approximately 1.5 m, which is less than the annual evaporation rate. Therefore, prolonged ponding over successive years would require additional significant runoff events to occur during the dry season.

It is likely that hydrologic responses from average, relatively frequent rainfall events are important in maintaining ecosystem function at the claypans, rather than rare larger runoff events. Based on the low EC measured for the ponded water within the claypans reported by Pinder et al (2017) and observed in the baseline logger data, ponded water appears to be sourced from surface water runoff. Persistent bodies of water in high evaporation areas generally become saline with time due to evaporative losses unless there are mechanisms for salt to leave the system. Generally, accumulated salt would be lost from the system through seepage to the groundwater or flushing downstream (via groundwater throughflow or surface water overflow). If seepage rates or surface outflow losses are high, it generally would not be expected that surface water pools would be persistent.

During earlier hydrological conceptualisation of the claypans, it was posited that seepage of fresh groundwater from the alluvial fan aquifer may contribute to maintaining water volume and quality in these claypans following large rainfall events. However, the currently collected field baseline data do not support this, and instead indicate water is lost from the claypans to the groundwater during ponding events based on the following:

- The locations of monitoring bores near the claypans are shown in Figure 10.2. The groundwater elevation in these bores is between ~1.7 and 3.5 m below the lowest ground surface elevation in the claypans. As shown in Figure 10.3, the groundwater levels are at ~400 mRL compared to the claypan elevation of ~402 mRL, indicating that groundwater does not flow into the claypans.
- Observed ponded water depths recede at a rate slightly greater than the expected evaporation losses. This indicates that seepage to the underlying groundwater system is likely to be occurring.
- The estimated mass of salt in the claypans from the logger data shows that the salt mass decreases as water levels recede, indicating a water loss mechanism other than evaporation is also occurring to remove salt from the system (i.e. seepage).
- Groundwater monitoring bores near the claypans show the greatest increase in water levels in response to rainfall events and an extended period of elevated groundwater levels coinciding with ponded water being contained in the claypans, indicating leakage from the claypans could be causing groundwater levels to rise, in addition to the wet season response observed in bores on the valley floor, further to the east.
- Salinity profiling data confirms saline groundwater underlying the claypans and time series EC data shows the mobilisation of salt from the unsaturated zone during periods of rainfall, indicating the saline water originates from surface water evaporation in the claypans.
- The limited field data collected suggests that evaporation, as opposed to seepage, plays the primary role in removing runoff from the claypans. Although evaporation may be the primary process in removing runoff, the above suggest that some seepage does also occur; the difference in surface water and groundwater RLs shows that this seepage has been insufficient to remove the unsaturated zone below the claypans.
- It is likely that frequent smaller rainfall/runoff events in between ponding wash accumulated salt through to the ground beneath the claypans. Salt will also be lost when the claypans overtop to the downstream environment.

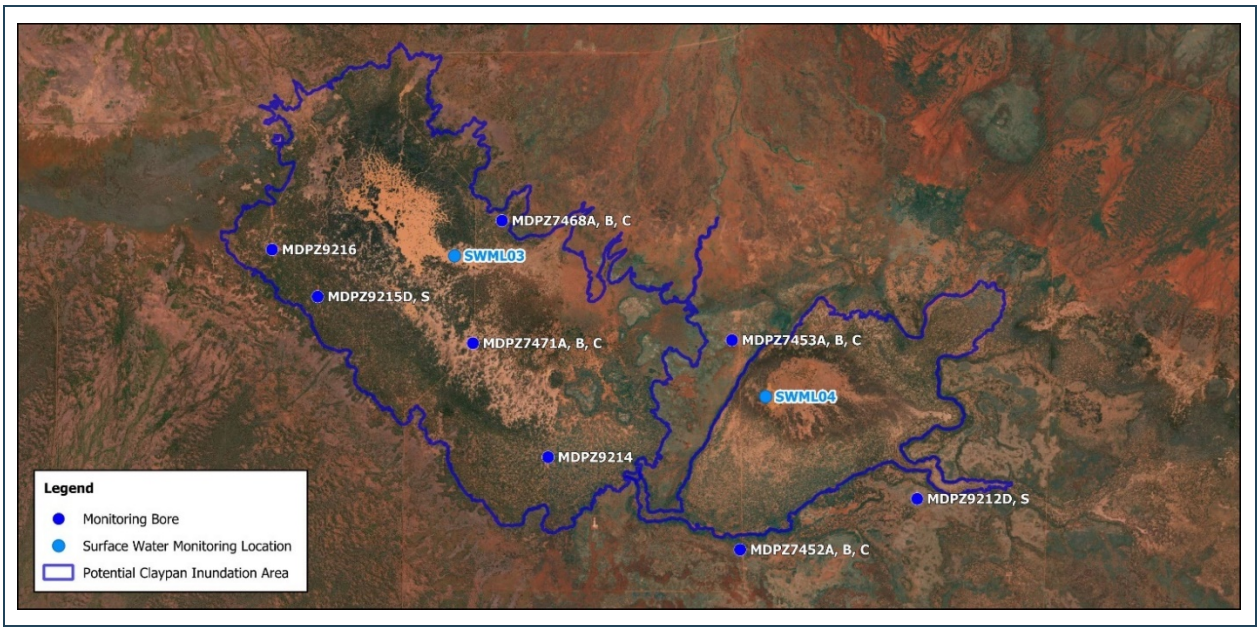


Figure 10.2 Groundwater and Surface Water Monitoring Sites in the Vicinity of the Claypans

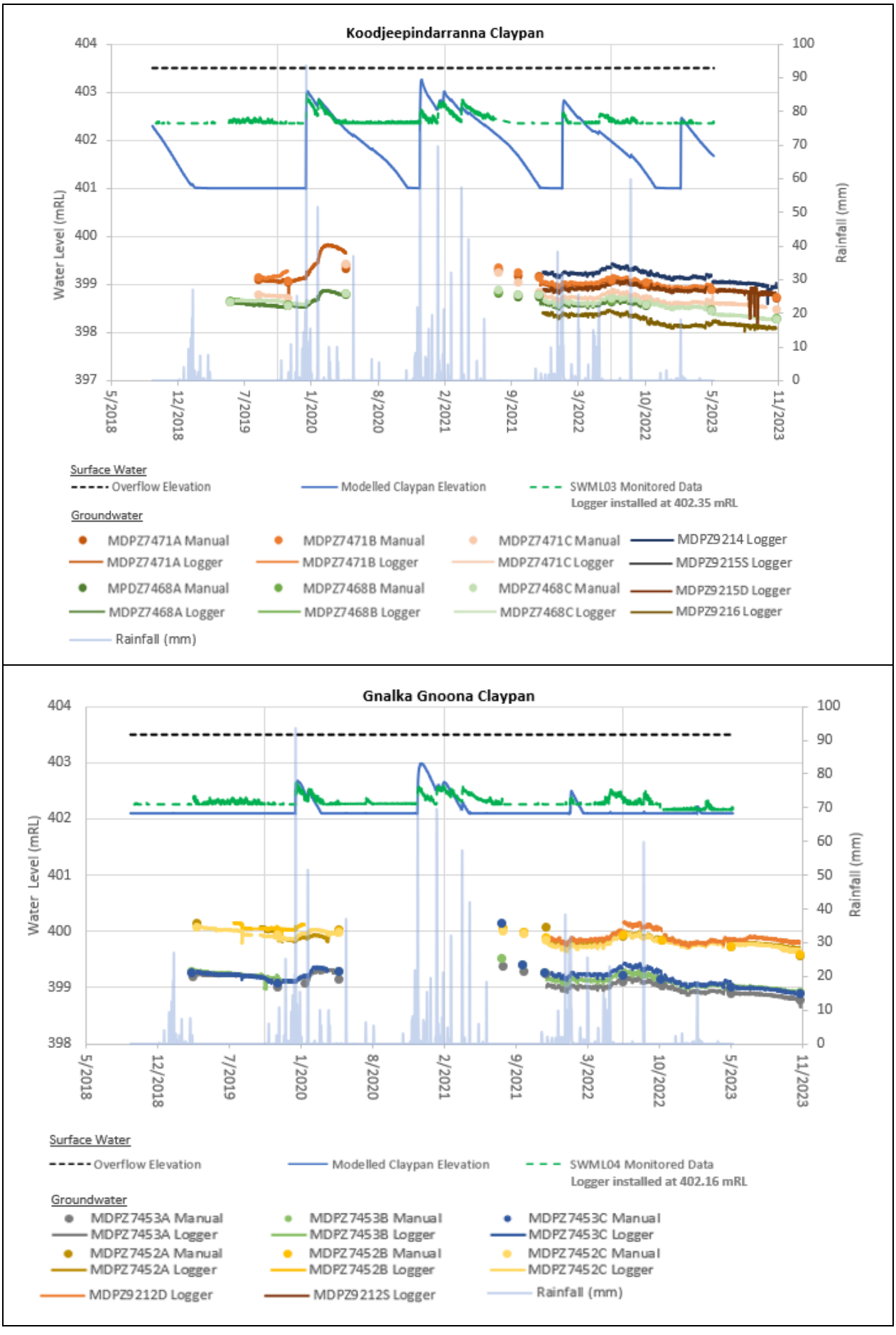


Figure 10.3 Groundwater and Surface Water Hydrographs for the Claypan Areas

The hydrological conceptualisation is summarised in Figure 10.4.

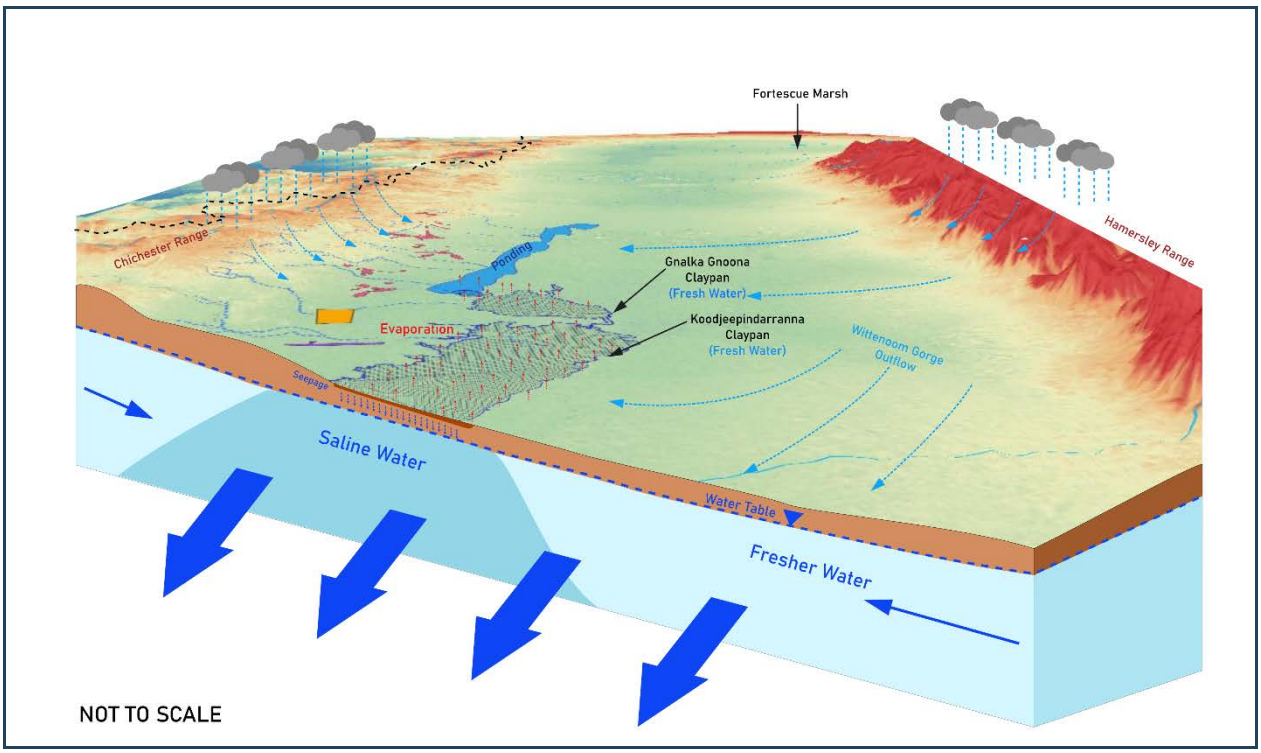


Figure 10.4 Claypan Hydrological Conceptualisation

10.7 Hydrogeology

The Jeerinah Formation outcrops along the northern boundary of the Study Area (in the Chichester Range) and underlies the Nammuldi Member of the Marra Mamba Formation. The Jeerinah Formation comprises black, pyritic and carbonaceous shale with minor chert beds when fresh and can weather to a pink, brown, white puggy clay. Available data suggest this unit, together with the lowermost unit of the Nammuldi Member (referred to as dolomitic Nammuldi by HPPL and often logged as Jeerinah Formation on site), is low permeability and forms a basement aquitard with minor local fractured aquifers. The fresh Jeerinah and Marra Mamba Formations have been grouped as one hydrostratigraphic unit.

Overlying this aquitard, in the Mulga East area, is a highly transmissive and continuous aquifer hosted in the Marra Mamba Formation (Nammuldi, Macleod and Mt Newman Members). The unit comprises interbedded BIF, shale, chert and some beds of dolomite, with secondary permeability resulting from mineralisation, fracturing and weathering processes. This unit, termed the "Altered Marra Mamba" unit outcrops along the northern flanks of the Fortescue Valley and sub-crops beneath the valley floor. A localised low permeability unit has been identified in the vicinity of MDPZ7451 and MDPZ7464, where the bedrock shale has weathered to become a 12 to 26 m thick saprolitic clay, and this may occur in other locations across the Study Area.

In the Mulga West area, based on limited hydrogeological data, the Altered Marra Mamba aquifer is believed to be much less extensive, occurring in localised areas and only at shallow depths immediately below the Tertiary overburden. As such, the majority of the Marra Mamba Formation in the Mulga West area is considered to be a low permeability, fresh basement aquitard with minor local fractures.

The West Angela Member (of the Wittenoom Formation) comprises interbedded BIF, shale, chert and dolomite and overlies the Altered Marra Mamba unit, sub-cropping the valley floor. In the Mulga East / Malay Well area this unit sub-crops in the vicinity of the claypans and hosts a moderately transmissive and continuous aquifer with highly transmissive, discontinuous aquifers associated with localised

mineralisation (as at MDPZ9211, 9212D and 9215D), weathering and/or fractures/faults (as at MDPZ9212D and MDPB0020). As with the Marra Mamba Formation, where shale of the West Angela Member has been exposed to weathering, it may occur as pale-coloured, waxy or puggy clay (i.e. at MDPZ9215D, MDPZ9214 and MDPZ9216). Although this puggy clay could be locally confining, current data does not show that it occurs as an extensive and continuous layer.

In Mulga West the West Angela Member occurs to the south of the Fortescue River, in the southwestern corner of the tenement. Although the hydraulic nature of the unit in this area is unknown at present (given the lack of relevant hydrogeological data), it is assumed to be similar to that in Mulga East/ Malay Well.

The Paraburdoo Member (of the Wittenoom Formation) overlies the West Angela Member and sub-crops the valley floor. Where intersected in the Malay Well area, the dolomite is generally light grey, fresh, crystalline, hard and of low permeability. However, a highly permeable zone of weathering has been identified at MDPZ7458A. Although the Paraburdoo Member often forms a regional aquifer elsewhere in the Pilbara, evidence to date suggests that in the Study Area it hosts a discontinuous fractured/weathered rock aquifer in generally low-permeability basement.

Although the HPPL geological model has no mapped faults, the mineral drilling in the Malay Well area (notably the juxtaposition of the Paraburdoo and West Angela Members) and geological observations at bores MDPZ9212D / MDPB0020 indicates faults may be present. The presence, orientation and hydraulic characteristics of any potential faulting is unknown and is recognised as an uncertainty.

Overlying the bedrock across the valley and along the lower slopes of the Chichester Range, is the Tertiary / Quaternary cover. This unit forms a transmissive aquifer and can be sub-divided as follows (from oldest to youngest):

- Basal Crete: Directly overlying the bedrock, ranging in colour from white / cream to beige / yellow-brown. Variable in both composition and nature occurring as calcrete, silcrete, dolomite or calcite, and ranging between hard, crystalline, massive, vuggy, brecciated and weathered; potentially weathering to a waxy clay.
- CID / Pisolite: Comprising both magnetic pisoliths (with varying red-brown silt to clay content) and hard, friable or vuggy grey-black CID.
- Undifferentiated Tertiary: Including scree/colluvium, detritals and alluvial fan material, it is predominantly red-brown in colour comprising BIF, chert and quartz gravel with varying silt and clay content / matrix; it may also include magnetic pisoliths (although not as a dominant component). Where intervals of clay occur (i.e. with no or minimal clasts), they tend to be between only 1 to 8 m thick. This unit has been found to be absent in some areas, resulting in the Upper Calcrete directly overlying the CID Pisolite unit.
- Upper Calcrete: Comprising white to light-brown, unstructured calcrete, often friable and sometimes vuggy; siliceous at some locations. Increases in thickness towards the centre of the valley with a maximum recorded thickness of ~40 m.
- Quaternary Cover: Unsaturated.

There is also lateritic hardcap development of Tertiary age on basement rocks that may be ferricrete (goethite). The differentiation between CID and hardcap can be difficult and there may be inconsistencies with the logging of this unit by both HPPL and AQ2. Where CID has been logged below the Basal Crete, a continuous channel aquifer could not be identified from the available data, therefore it has been classified, at present, as a local, discontinuous hardcap aquifer. Where the Basal Crete has “pinched out” on the northern slopes of the valley, differentiation between the CID and hardcap needs further consideration.

10.8 Aquifer Parameters

Table 10.1 presents the estimated aquifer parameters for each of the hydrogeological units (from field data, where available, as well as regional data sets).

In summary, the Study Area is dominated by high permeability units (aquifers) with the only low permeability units (aquitards) being:

- Dolomite of the Wittenoom Formation (Paraburdoo Member) underlying the valley area (with only localised fractures / weathering being identified to date as potential sources of permeability).
- The Jeerinah Formation and unaltered (fresh) bedrock of the Marra Mamba Formation which outcrop in the north of the Study Area and occur, at depth, below the Altered Marra Mamba aquifer.
- Clay interval at the Tertiary / bedrock interface, believed to be weathered shale and discontinuous.

Table 10.1 Summary of Hydraulic Parameters

Unit		Range in Thickness (m)	Range of Permeability[1] (m/d)	Adopted Permeability[2] (m/d)	No of Aquifer Tests	Confined Storage (unitless)	Specific Yield (%)
Tertiary Cover	Upper Calcrete	0 to 30	2 to 63	10	13	1x10-6	1-5%
	Undifferentiated Tertiary	0 to 45	2 to 365	8	18	1x10-5	5%
	Pisolite / CID	0 to 23	5 to 92	14	10	1x10-5	5%
	Basal Crete	0 to 22	3 to 33	9	8	1x10-6	1-3%
Bedrock	Dolomite of Wittenoom Fm (Fresh) - Localised Weathering	-	0.001 to 10	0.01	0	1x10-4	1%
	West Angela Mbr	-	0.01 to 10	2	0	1x10-4	1%
	West Angela Hardcap / Ore	-	11 to 131	20	6	1x10-6	1-5%
	Altered Marra Mamba: Marra Mamba Ore (with mineralised CID)	-	10 to 57	25	8	1x10-6	3%
	Altered Marra Mamba: Unmineralised / Fractured Marra Mamba	-	2 to 174	10	12	1x10-3	1%
	Fresh Jeerinah and Marra Mamba – Minor Fractures	-	0.015 to 0.022	0.01	4	1x10-4	1%

Notes:

1 Maximum and minimum permeability values derived from test analysis. For maximum and minimum values based on 90% confidence limits refer to Table 6.3

2 Refer Section 6.2, Table 6.3

For those units not tested in the Study Area, regional values have been adopted.

Because of the complex response of multi-aquifer systems, confined storage estimates have only been made for a limited number of bores; adopted values also take into account regional experience.

In high transmissivity confined aquifers where a large drawdown is required to develop unconfined conditions, it is generally not practicable for pumping tests to be of sufficient duration or volume to allow this to occur. Stress on such aquifers sufficient to achieve unconfined conditions is commonly not incurred until operational dewatering or long-term water supply pumping. This is the situation for confined aquifers in the Study Area and estimates of specific yield cannot be made from the pumping test data. Consequently, the adopted values of specific yield are based on regional experience.

10.9 Recharge

Recharge to the groundwater system occurs as diffuse recharge from rainfall events. Recharge generally occurs on an annual basis during the summer wet season, with cyclonic events resulting in significant rises in water level. Recharge occurs to a varying degree across the entire Study Area:

- On the valley flanks where the Marra Mamba outcrops.
- Infiltration into the Tertiary / Quaternary overburden where runoff is focused on the valley floor.

The greatest response to rainfall is evident at the western end of the valley, in the vicinity of the Koodjeepindarranna Claypan. In this area, observations from the water level hydrographs (Figure 10.5) indicate a subdued and delayed response to rainfall recharge in the Undifferentiated Tertiary of the northern alluvial fan (at MDPZ7459), whilst a more rapid response is evident in the bedrock, Basal Crete and CID/Pisolite units near the claypan (i.e. at Bores MDPZ97468A, B & C and MDPZ7471 A and B), refer Figure 10.5. Although a significant response to rainfall is evident in the Upper Calcrete, the manual reading taken in December 2021 at MDPZ7471 indicates the response may be slightly delayed, dependent on seepage through the overlying Quaternary cover (comprising a 2 m layer of clay at this location, near the claypan).

Bores at higher elevations, and with greater depths to water, only show a muted response to seasonal rainfall as a result of both lower rates of recharge and a greater vadose-zone moisture deficit that will intercept infiltrating water.

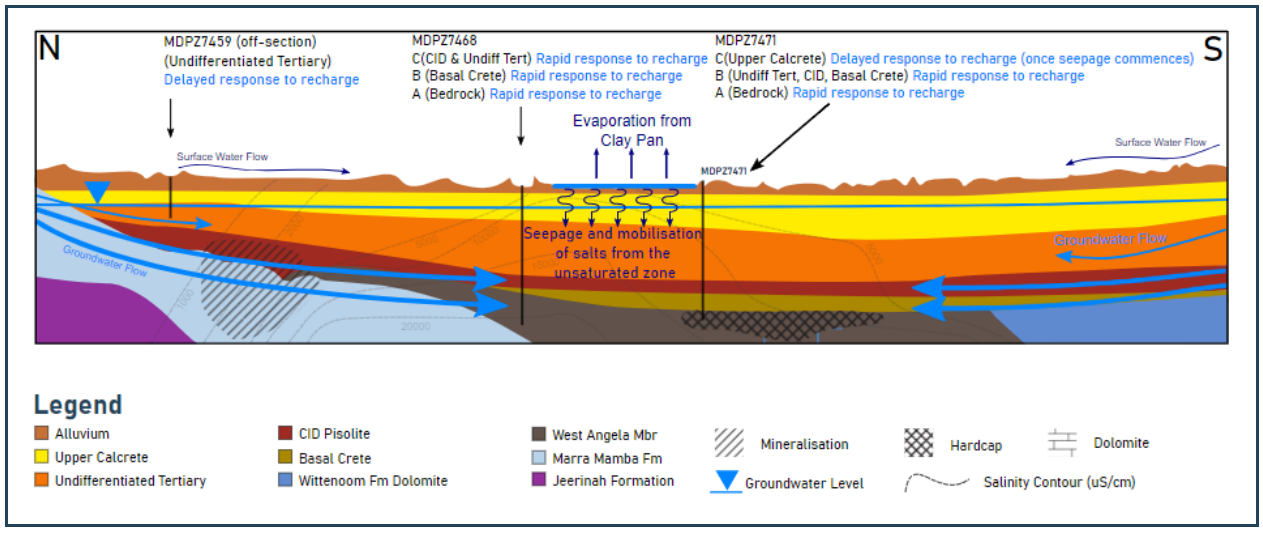


Figure 10.5 Hydrogeological Cross-Section Showing Recharge

10.10 Groundwater Levels and Groundwater Flow

The water table elevation ranges between approximately 420 mRL and 398 mRL across the Study Area, down to 385 mRL in the Mulga West area. Groundwater flows from the topographically higher areas into the valley and then in a northwesterly direction along the valley (refer Figure 6.8). In the Mulga East / Malay Well area, the hydraulic gradient is gentle across the lower lying areas, indicative of transmissive aquifers (and / or low rates of groundwater flow), and steepens along the northern boundary of the Study Area, indicative of lower transmissivity units. Hydraulic gradients also steepen down gradient of the Study Area, at the western end of Mulga West, indicative of a less transmissive setting, the narrowing of the valley and / or increased groundwater throughflow from the Hamersley Ranges / Hamersley Gorge. Localised areas of groundwater mounding or preferential flow along permeable structures may be present across the Mulga East orebody area, however, there are insufficient data to validate this concept.

The depth to groundwater is shallow in the lower lying, valley areas (i.e. approximately 3 to 5 mbgl) and increases with elevation, to depths of up to 45 mbgl (at MDPZ7467) in the more elevated areas (i.e. in the more northern section of the proposed pits).

10.11 Hydraulic Connection

Hydraulic connection between the units is evident both laterally (from the groundwater level contours) and vertically (from the cluster bore data and limited clay / low permeability horizons). Vertical gradients are only evident at a few cluster and paired bore locations where saprolitic clays or thin intervals of more

clayey Tertiary materials are present. Due to variations in water salinity and density, water level equilibration or difference does not always equate to a corresponding difference in potentiometric pressure. On an area wide scale, it is likely the valley aquifers are in vertical hydraulic connection with local areas of separation caused by low permeability intermediating units (such as the saprolitic clay). Although there is no discernable trend in where upward or downward gradients occur, changes in hydraulic gradients in response to wet season recharge are evident in two sets of cluster bores near the Koodjeepindarranna Claypan and the southern alluvial fan (i.e. MDPZ7471 and MDPZ7462 respectively) where an upward gradient exists in the drier periods (i.e. November 2019) and a downward gradient is present after the 2019/20 wet season (i.e. May 2020). This local change likely represents the process of wet season recharge (refer Figure 10.5).

10.12 Groundwater Water Quality

The groundwater across the valley area, is generally "mature", chloride and sodium dominant, suggesting the groundwater has been subjected to evapotranspiration and / or mineral dissolution since it was recharged or it has been affected by the leaching of salts from the claypan areas (which derive from evaporation). Bicarbonate dominant groundwater, indicative of recharge waters, occurs in the vicinity of the alluvial fan between the two claypans, with the groundwater across the majority of the orebody area having no dominant cations or anions, indicative of the mixing or dissolution processes. Isolated areas show chloride dominant groundwater with no dominant cation in areas where clay rich facies in the Tertiary Detritals or weathered shale have been identified; typically this results from cation exchange caused by the clay minerals.

The groundwater across the Study Area ranges from fresh to saline and is generally slightly acidic to slightly alkaline. Concentrations of TDS range from 180 mg/L (EC 300 µS/cm) in the upper reaches of the groundwater system to 17,000 mg/L (EC 23,000 µS/cm) in the valley area near the claypans and ~2,500 to 12,500 mg/L (4,000 to 20,000 µS/cm) in the Mulga West valley area. The pH of the groundwater generally ranges between 5.9 and 7.9, however, in the northernmost bores, the groundwater is more acidic at depth (i.e. between pH 3.6 and 4.4) due to the likely oxidation of sulphides within the Jeerinah Formation.

Groundwater in the upper reaches of the system (i.e. in the north of the Study Area) is fresh, becoming more saline in the valley area. Salinity profiling data confirms saline groundwater underlying the claypans and time series EC data shows the mobilisation of salts from the unsaturated zone during periods of rainfall, indicating the saline water originates from surface water evaporation in the claypans. The groundwater salinity generally increases with depth (as would be expected, due to density effects), although further from the valley, the depth of the fresher groundwater increases such that the bores along the northern boundary of the Study Area (at higher elevations) show no change in the salinity profiles. Some bores located on the lower terrain show discrete intervals of increased or reduced salinity which generally correspond to zones of high permeability, indicating potential preferential lateral flow through these units.

10.13 Hydrology of the of the *E Victrix* Woodland Communities

The conceptual ecohydrological model of *E. victrix* woodland communities includes the following key processes:

- Annual replenishment of the vadose zone occurs from a combination of incident rainfall and infiltration during inundation-events. The combined contribution of rainfall and surface inflows is estimated to range between 200 mm/yr during drought conditions, 490 mm/yr during average conditions and 770 mm/yr during wet conditions (the latter have been experienced since 1996). This results in sufficient vadose-zone replenishment to support the vegetation communities.

- Soil moisture in the root zone progressively reduces in between replenishment events; as indicated by time series leaf water potential measurements with predawn LWP <-0.5 MPa. This triggers conservative water use behaviour by the trees (i.e. stomatal closure) and reduced growth. Based on midday LWP measurements, cessation of transpiration by *E. victrix* is estimated to occur at approximately -5.0 MPa. Owing to low soil hydraulic conductivity and/or the presence of massive calcrete, soil water replenishment by capillary rise from the water table is minimal.
- It is estimated that there is sufficient rainfall to at least partially inundate the claypans every two years on average and infiltration appears to occur over a prolonged period of several months. Ponded water contributes to moisture availability in the vadose zone around the claypan waterbody fringes. Subsoils may become periodically waterlogged.
- Subsoil percolation, although strongly attenuated, is sufficient to flush salt deriving from evapo-concentration in the vadose zone into the underlying groundwater system.
- Surface throughflows during the largest flood events is infrequent but assumed to also contribute to salt flushing from the system.

10.14 Ecohydrological Baseline for the *E. victrix* woodlands

Based on the aggregate findings of the ecohydrological assessment, it is concluded that *E. victrix* trees in the open woodland/woodland formations of the Fortescue Valley are not phreatophytic. The natural (i.e. pre-disturbance) baseline is summarised as follows:

- The *E. victrix* woodlands occur in relatively tree low density, open formations across landscape units of the Fortescue Valley (SBA range = 2-10 m^2/ha in patches; with broader landscape SBA of about 3- 5 m^2/ha). Inter-patch variation is attributable to heterogeneity in soil depth, texture and terrain characteristics affecting the capture and infiltration of surface inflows from upgradient areas. In the lowest depressions, prolonged waterlogging may ultimately constitute a constraint to woodland persistence.
- The woodland structure is dominated by large, mature trees. Recruitment occurs episodically during wet climate phases; however, recruitment efficacy (i.e. percentage conversion of seedlings into mature trees) is low, as the young trees succumb to drought stress exacerbated by competition with mature trees and understorey grasses where present. Other mortality factors such as herbivory by insects and cattle may also be relevant and interactive with drought stress.
- Tree root systems are relatively shallow, owing to subsoil constraints include calcrete sheeting and/or dense, high bulk density clay that is prone to waterlogging. However, the root systems are laterally expansive and extend well beyond the tree canopy radius.
- The woodland trees are regularly exposed to drought stress and have various drought tolerance adaptations. Prevalent water use regulation (i.e. stomatal closure) is indicated by suppressed stem growth rates. The leaf area index (LAI) of the woodland stands fluctuates through time in response to soil moisture. Adjustments to reduced soil moisture include leaf shedding, limb dropping and under more extreme conditions selective tree deaths (self-thinning). Adjustments to increased soil moisture include leaf growth flushes and seedling recruitment. The likely range of SBA fluctuation associated with these processes is circa ±30%.
- Vadose zone soil water replenishment is facilitated by infiltrated rainfall, with augmentation by surface inflows in areas, as dictated by catchment hydrology. At the landscape scale, the transpiration flux of woodland trees is in the order of 100 to 150 mm/year during more favourable climate sequences and 50 to 100 mm/year during drier sequences. Soil and understorey evaporation generally account for the balance of rainfall, with the ratio of T/ET being in the order of 30 to 40%. In areas where PAW is augmented by inundation, then evaporation will also occur directly from standing water bodies. The EWB modelled soil evaporation rates are consistent with actual measurements in the central Pilbara by Tugwell-Wootton et al. (2020).

11. CONCLUSION

AQ2 have undertaken comprehensive groundwater, surface water and ecohydrological investigations across the Study Area since 2018, inclusive of an on-going programme of groundwater and surface water monitoring. The findings from these studies have been combined to develop an integrated conceptual model for the area, with specific focus on the culturally and environmentally sensitive wetlands of the Fortescue Valley, inclusive of the Gnalka Gnoona and Koodjeepindarranna Claypans. The data which has been collected serves to document the hydrological environmental conditions across the site prior to the development of the proposed Project.

It is intended that this baseline dataset and conceptual understanding of the site will continue to be developed as more monitoring data becomes available such that potential detrimental impacts resulting from the proposed Project can be identified and managed appropriately. The baseline data and conceptual model is being used to develop an environmental impact assessment for the proposed Project.

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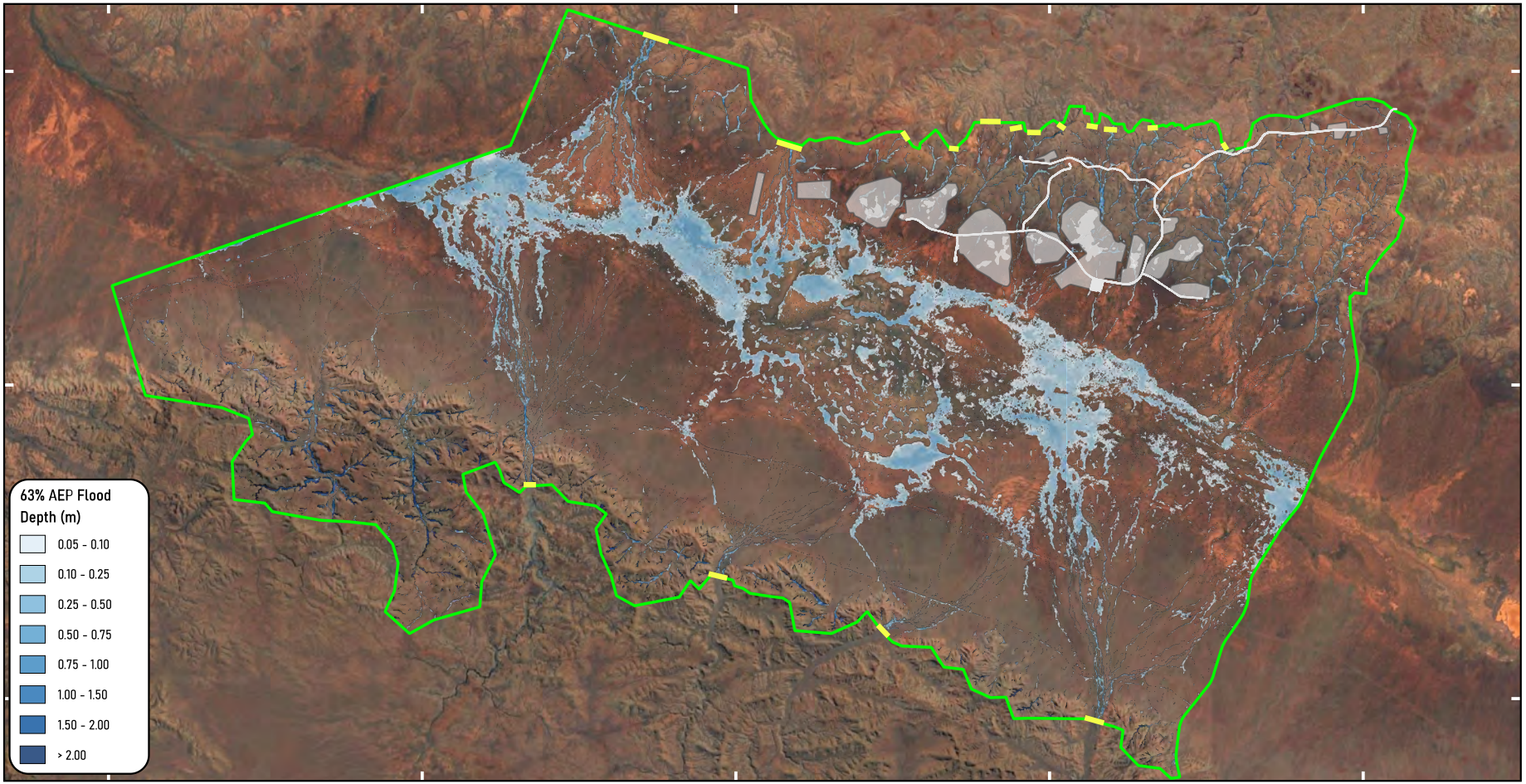
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APPENDIX A
FLOOD MAPPING



N

4 8 km

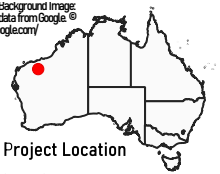
GDA94 / MGA zone 50

Legend

- Model Inflow
- Rain On Grid Model Boundary
- Proposed Haul Road
- Surface Water Containment Area
- Proposed Pit Footprint (MDE_LOM_20)

- Predicted maximum flood depths are from the simulation period of a 2D HEC RAS model developed using LIDAR data from 2023, excluding depths less than 0.05m.
- The purpose of the model was to simulate hydrological conditions within, and immediately downstream of, mine development areas associated with the Mulga Downs Project.
- Inflow hydrographs were input around the boundary of the model and rain-on-grid calculations used to simulate runoff across the model domain.
- Flood depths upstream of the inflow boundary conditions are not valid.
- Depths of ponded water within the valley floor (e.g., in the claypans) are likely to be underpredicted as not all runoff from within the model will have drained by the end of the simulation period
- Maximum water levels resulting from rainfall-runoff (modelled depths) and claypan storage (contour) are unlikely to occur simultaneously as they will be driven by different magnitude and duration rainfall events.
- Outflow water depths along the north-east of the model boundary are not valid.

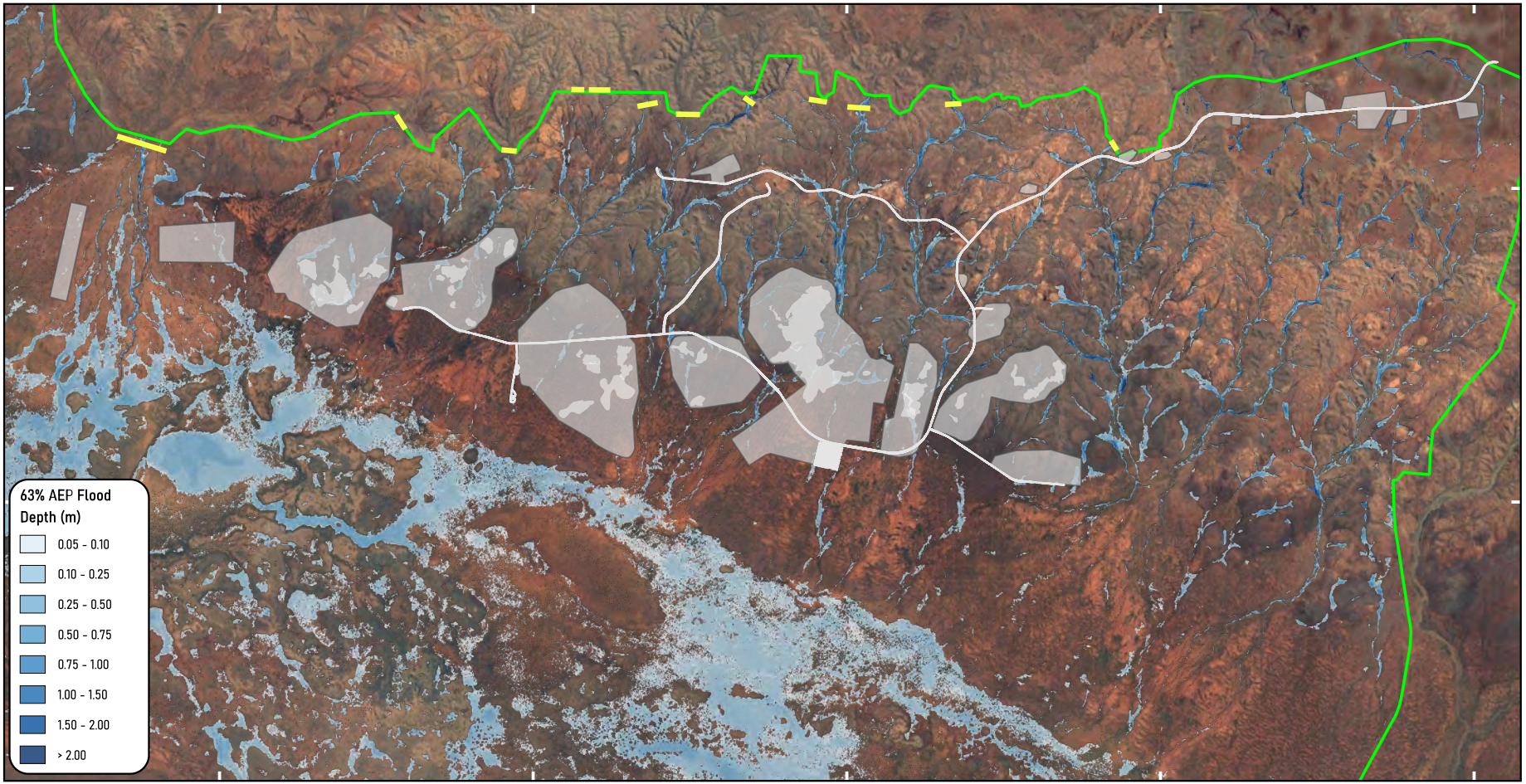
Data sources: Background Image: Base map and data from Google. © https://www.google.com/



J:\777\A.GIS\Workspaces\A92b Figures\Appendix A.qgz: Figure A1 – 63% Depth (plan1)

AQ2

Hydrology Figure A1
Baseline Scenario
63% AEP Flood Depth



N

2 4 km

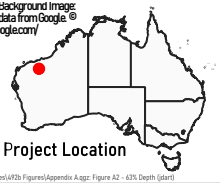
GDA94 / MGA zone 50

Legend

- Model Inflow
- Rain On Grid Model Boundary
- Proposed Haul Road
- Surface Water Containment Area
- Proposed Pit Footprint (MDE_LOM_20)

- Predicted maximum flood depths are from the simulation period of a 2D HEC RAS model developed using LIDAR data from 2023, excluding depths less than 0.05m.
- The purpose of the model was to simulate hydrological conditions within, and immediately downstream of, mine development areas associated with the Mulga Downs Project.
- Inflow hydrographs were input around the boundary of the model and rain-on-grid calculations used to simulate runoff across the model domain.
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- Outflow water depths along the north-east of the model boundary are not valid.

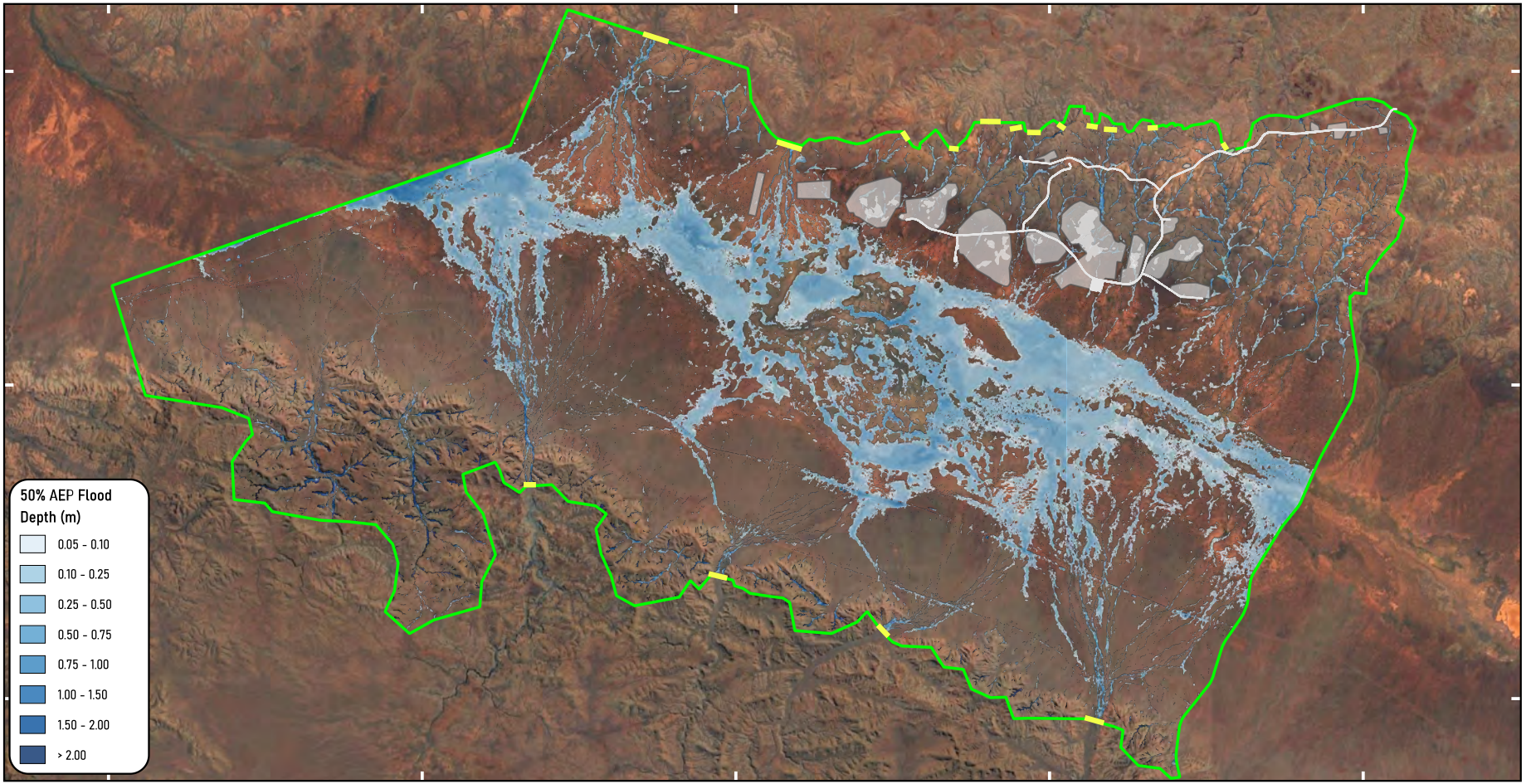
Data sources: Background Image: Base map and data from Google. © https://www.google.com/



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AQ2

Hydrology Figure A2
Baseline Scenario
63% AEP Flood Depth



N

4 8 km

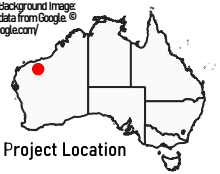
GDA94 / MGA zone 50

Legend

- Model Inflow
- Rain On Grid Model Boundary
- Proposed Haul Road
- Surface Water Containment Area
- Proposed Pit Footprint (MDE_LOM_20)

- Predicted maximum flood depths are from the simulation period of a 2D HEC RAS model developed using LIDAR data from 2023, excluding depths less than 0.05m.
- The purpose of the model was to simulate hydrological conditions within, and immediately downstream of, mine development areas associated with the Mulga Downs Project.
- Inflow hydrographs were input around the boundary of the model and rain-on-grid calculations used to simulate runoff across the model domain.
- Flood depths upstream of the inflow boundary conditions are not valid.
- Depths of ponded water within the valley floor (e.g., in the claypans) are likely to be underpredicted as not all runoff from within the model will have drained by the end of the simulation period
- Maximum water levels resulting from rainfall-runoff (modelled depths) and claypan storage (contour) are unlikely to occur simultaneously as they will be driven by different magnitude and duration rainfall events.
- Outflow water depths along the north-east of the model boundary are not valid.

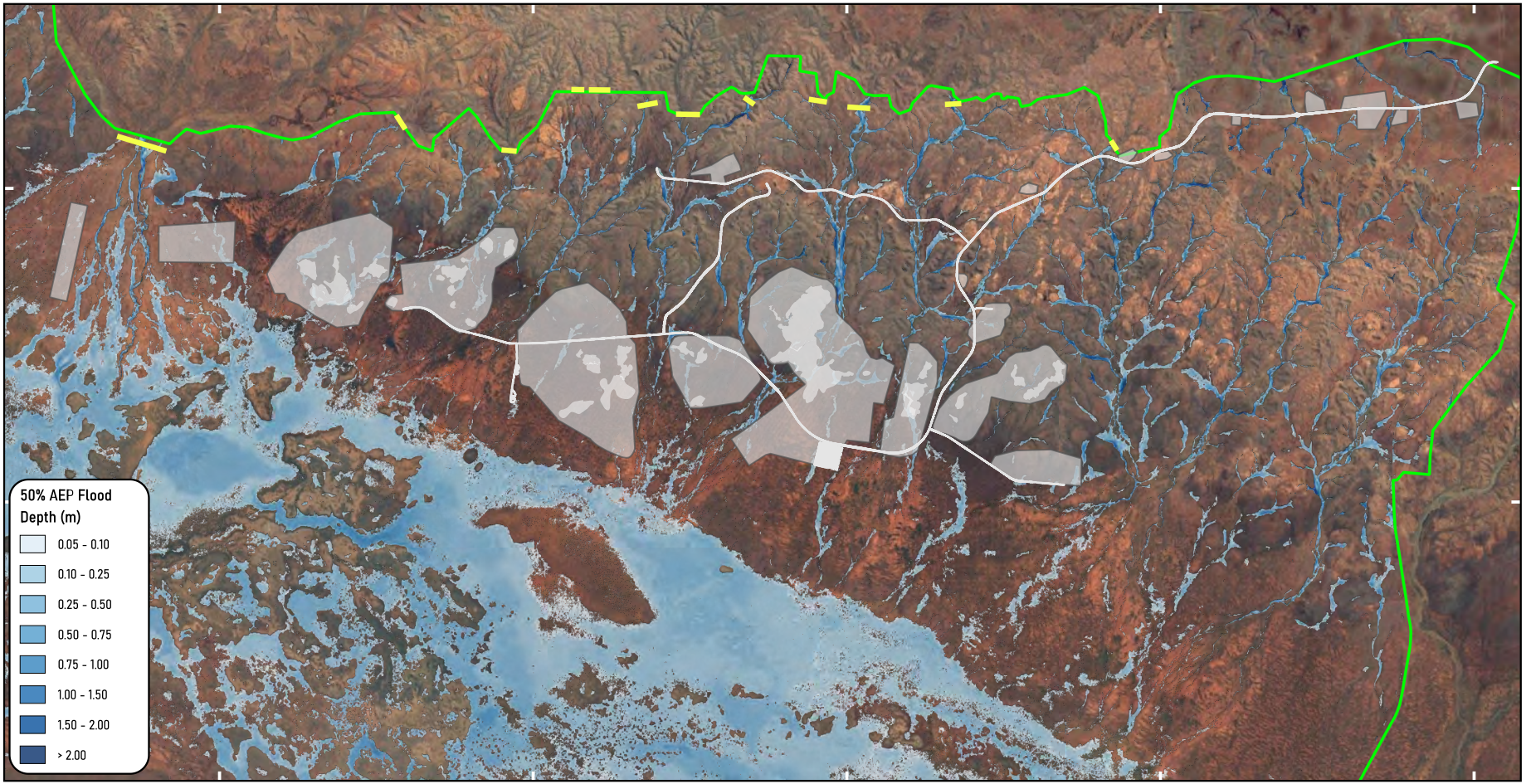
Data sources: Background Image: Base map and data from Google. © https://www.google.com/



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AQ2

Hydrology Figure A3
Baseline Scenario
50% AEP Flood Depth



N

2 4 km

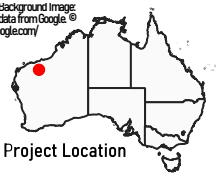
GDA94 / MGA zone 50

Legend

- Model Inflow
- Rain On Grid Model Boundary
- Proposed Haul Road
- Surface Water Containment Area
- Proposed Pit Footprint (MDE_LOM_20)

- Predicted maximum flood depths are from the simulation period of a 2D HEC RAS model developed using LIDAR data from 2023, excluding depths less than 0.05m.
- The purpose of the model was to simulate hydrological conditions within, and immediately downstream of, mine development areas associated with the Mulga Downs Project.
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- Outflow water depths along the north-east of the model boundary are not valid.

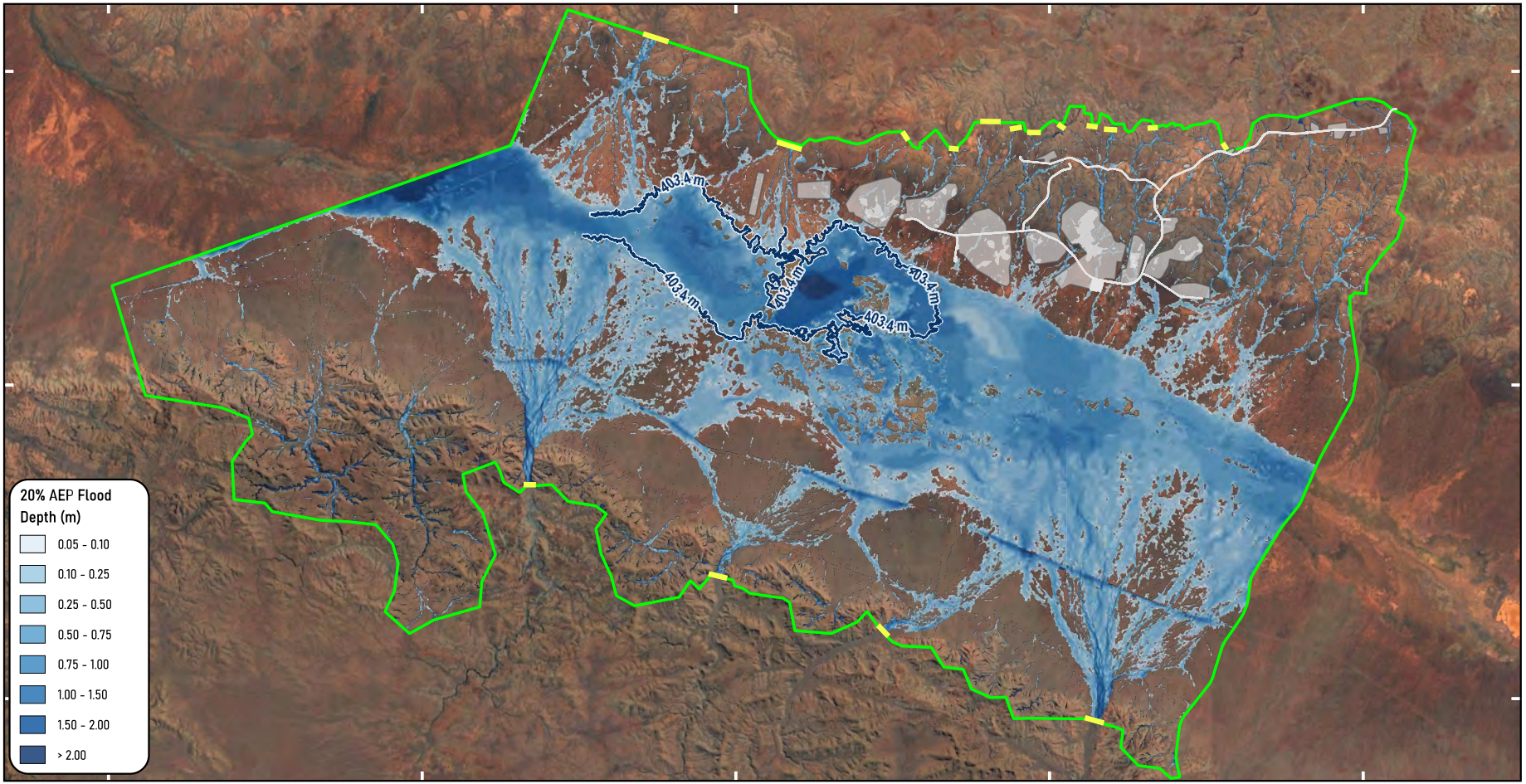
Data sources: Background Image: Base map and data from Google. © https://www.google.com/



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AQ2

Hydrology Figure A4
Baseline Scenario
50% AEP Flood Depth



N

4 8 km

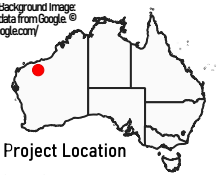
GDA94 / MGA zone 50

Legend

- Model Inflow
- Rain On Grid Model Boundary
- 20% AEP Claypan Level (403.4 mRL)
- Proposed Haul Road
- Surface Water Containment Area
- Proposed Pit Footprint (MDE_LOM_20)

- Predicted maximum flood depths are from the simulation period of a 2D HEC RAS model developed using LIDAR data from 2023, excluding depths less than 0.05m.
- The purpose of the model was to simulate hydrological conditions within, and immediately downstream of, mine development areas associated with the Mulga Downs Project.
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- Outflow water depths along the north-east of the model boundary are not valid.

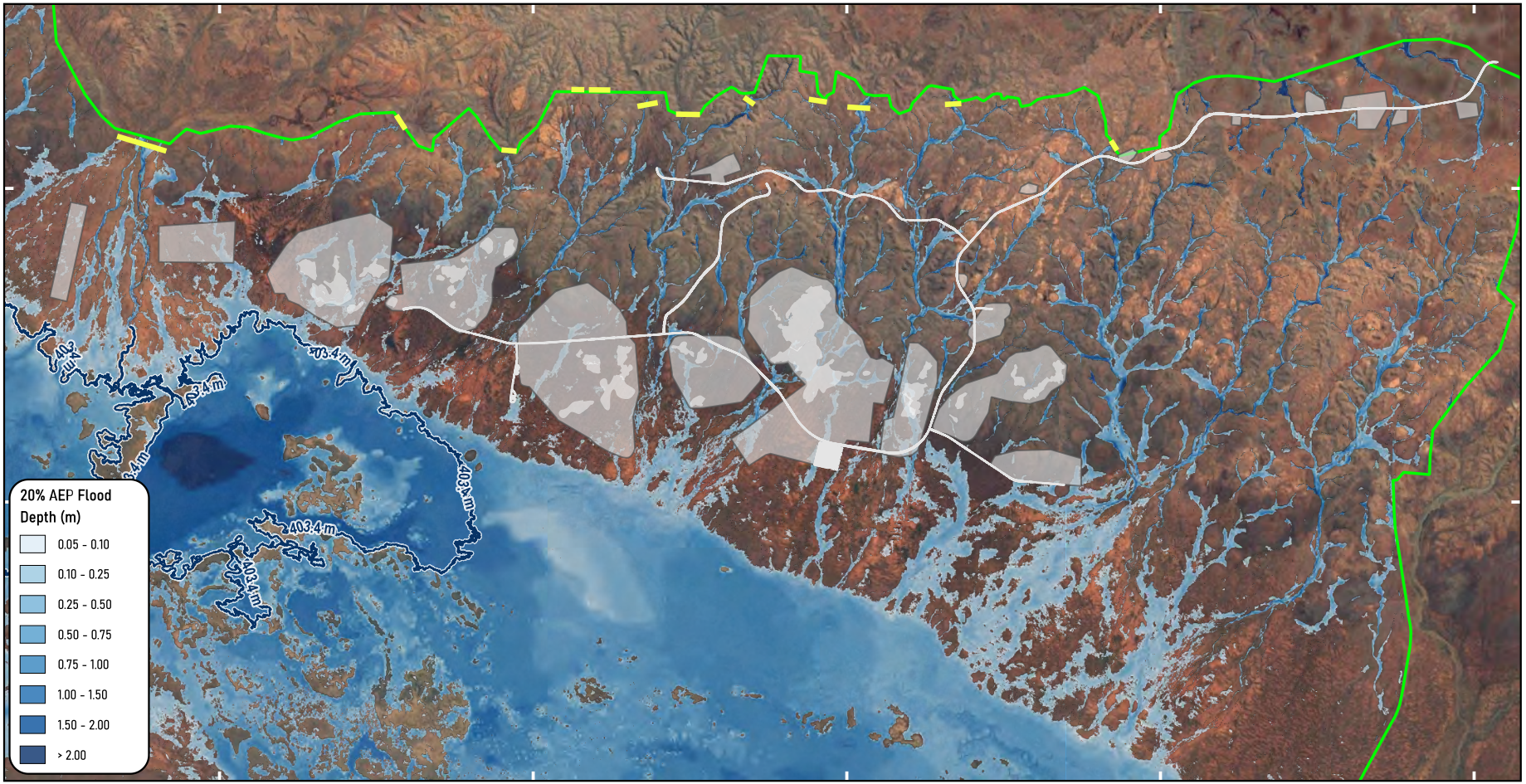
Data sources: Background Image: Base map and data from Google. © https://www.google.com/



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AQ2

Hydrology Figure A5
Baseline Scenario
20% AEP Flood Depth



N

2 4 km

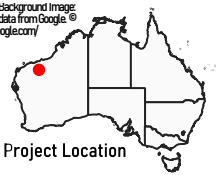
GDA94 / MGA zone 50

Legend

- Model Inflow
- Rain On Grid Model Boundary
- 20% AEP Claypan Level (403.4 mRL)
- Proposed Haul Road
- Surface Water Containment Area
- Proposed Pit Footprint (MDE_LOM_20)

- Predicted maximum flood depths are from the simulation period of a 2D HEC RAS model developed using LIDAR data from 2023, excluding depths less than 0.05m.
- The purpose of the model was to simulate hydrological conditions within, and immediately downstream of, mine development areas associated with the Mulga Downs Project.
- Inflow hydrographs were input around the boundary of the model and rain-on-grid calculations used to simulate runoff across the model domain.
- Flood depths upstream of the inflow boundary conditions are not valid.
- Depths of ponded water within the valley floor (e.g., in the claypans) are likely to be underpredicted as not all runoff from within the model will have drained by the end of the simulation period
- Maximum water levels resulting from rainfall-runoff (modelled depths) and claypan storage (contour) are unlikely to occur simultaneously as they will be driven by different magnitude and duration rainfall events.
- Outflow water depths along the north-east of the model boundary are not valid.

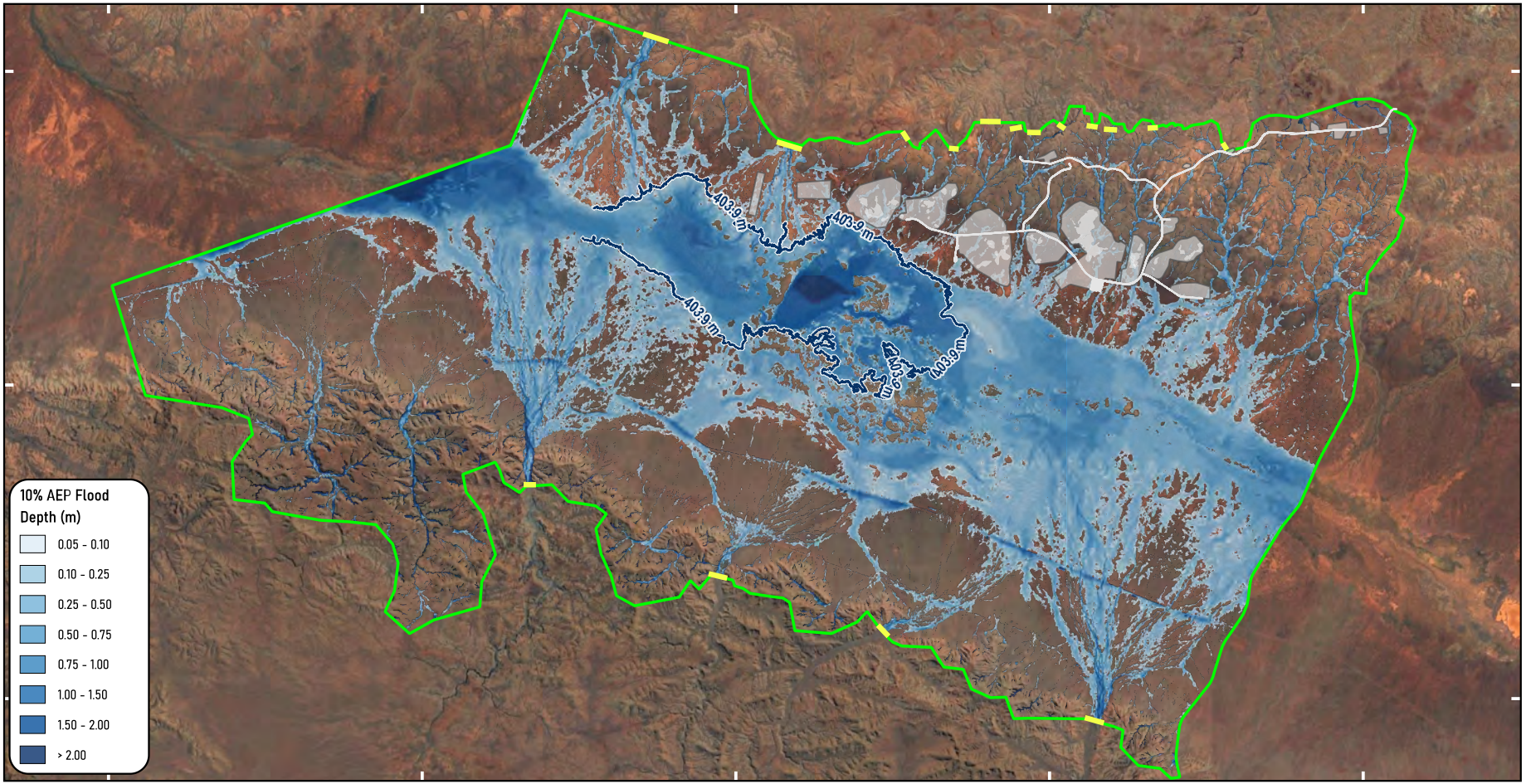
Data sources: Background Image: Base map and data from Google. © https://www.google.com/



P:\777\A.GIS\Workspaces\692b Figures\Appendix A.qgz: Figure A6 - 20% Depth (start)

AQ2

Hydrology Figure A6
Baseline Scenario
20% AEP Flood Depth



N

4 8 km

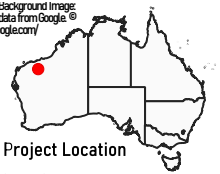
GDA94 / MGA zone 50

Legend

- Model Inflow
- Rain On Grid Model Boundary
- 10% AEP Claypan Level (403.9 mRL)
- Proposed Haul Road
- Surface Water Containment Area
- Proposed Pit Footprint (MDE_LOM_20)

- Predicted maximum flood depths are from the simulation period of a 2D HEC RAS model developed using LIDAR data from 2023, excluding depths less than 0.05m.
- The purpose of the model was to simulate hydrological conditions within, and immediately downstream of, mine development areas associated with the Mulga Downs Project.
- Inflow hydrographs were input around the boundary of the model and rain-on-grid calculations used to simulate runoff across the model domain.
- Flood depths upstream of the inflow boundary conditions are not valid.
- Depths of ponded water within the valley floor (e.g., in the claypans) are likely to be underpredicted as not all runoff from within the model will have drained by the end of the simulation period
- Maximum water levels resulting from rainfall-runoff (modelled depths) and claypan storage (contour) are unlikely to occur simultaneously as they will be driven by different magnitude and duration rainfall events.
- Outflow water depths along the north-east of the model boundary are not valid.

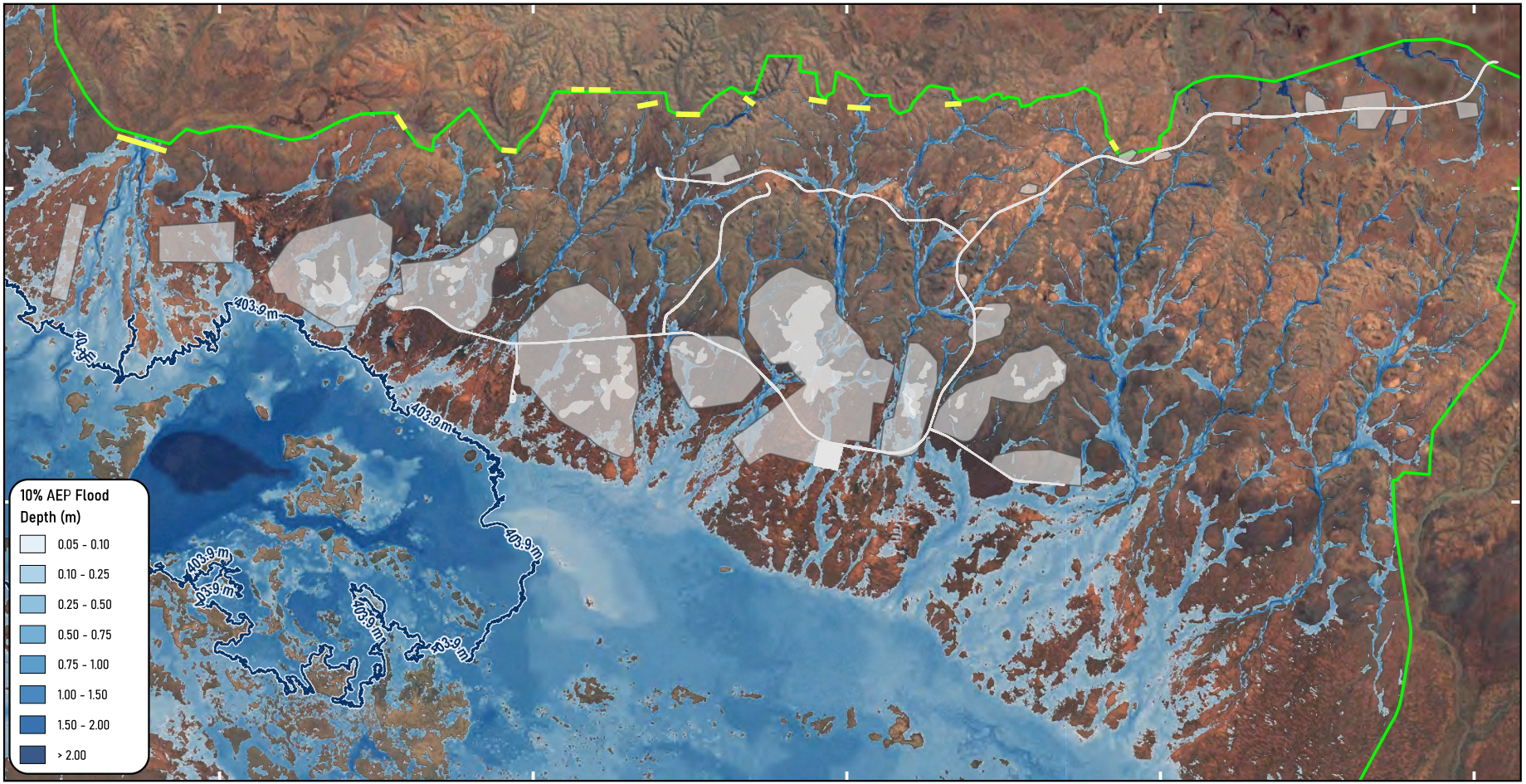
Data sources: Background Image: Base map and data from Google. © https://www.google.com/



P:\7711\A\GIS\Workspaces\492b Figures\Appendix A.qgz: Figure A7 – 10% Depth (plan1)

AQ2

Hydrology Figure A7
Baseline Scenario
10% AEP Flood Depth



N

2 4 km

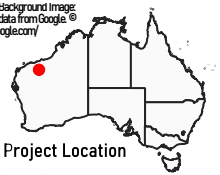
GDA94 / MGA zone 50

Legend

- Model Inflow
- Rain On Grid Model Boundary
- 10% AEP Claypan Level (403.9 mRL)
- Proposed Haul Road
- Surface Water Containment Area
- Proposed Pit Footprint (MDE_LOM_20)

- Predicted maximum flood depths are from the simulation period of a 2D HEC RAS model developed using LIDAR data from 2023, excluding depths less than 0.05m.
- The purpose of the model was to simulate hydrological conditions within, and immediately downstream of, mine development areas associated with the Mulga Downs Project.
- Inflow hydrographs were input around the boundary of the model and rain-on-grid calculations used to simulate runoff across the model domain.
- Flood depths upstream of the inflow boundary conditions are not valid.
- Depths of ponded water within the valley floor (e.g., in the claypans) are likely to be underpredicted as not all runoff from within the model will have drained by the end of the simulation period
- Maximum water levels resulting from rainfall-runoff (modelled depths) and claypan storage (contour) are unlikely to occur simultaneously as they will be driven by different magnitude and duration rainfall events.
- Outflow water depths along the north-east of the model boundary are not valid.

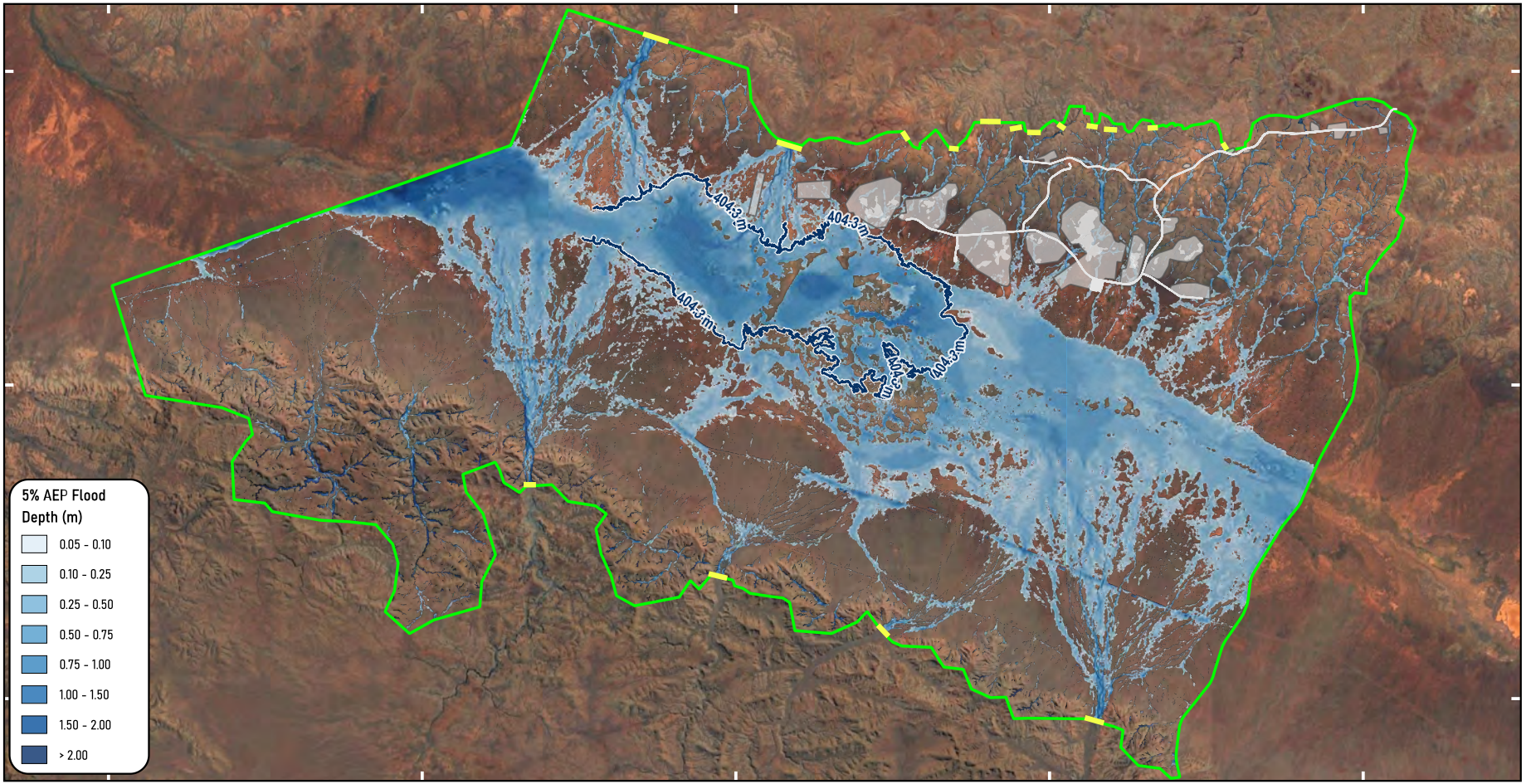
Data sources: Background Image: Base map and data from Google. © https://www.google.com/



P:\177\A.GIS\Workspaces\492b Figures\Appendix A.qgz: Figure A8 – 10% Depth (plan1).

AQ2

Hydrology Figure A8
Baseline Scenario
10% AEP Flood Depth



N

4 8 km

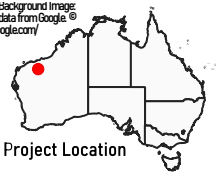
GDA94 / MGA zone 50

Legend

- Model Inflow
- Rain On Grid Model Boundary
- 5% AEP Claypan Level (404.3 mRL)
- Proposed Haul Road
- Surface Water Containment Area
- Proposed Pit Footprint (MDE_LOM_20)

- Predicted maximum flood depths are from the simulation period of a 2D HEC RAS model developed using LIDAR data from 2023, excluding depths less than 0.05m.
- The purpose of the model was to simulate hydrological conditions within, and immediately downstream of, mine development areas associated with the Mulga Downs Project.
- Inflow hydrographs were input around the boundary of the model and rain-on-grid calculations used to simulate runoff across the model domain.
- Flood depths upstream of the inflow boundary conditions are not valid.
- Depths of ponded water within the valley floor (e.g., in the claypans) are likely to underpredicted as not all runoff from within the model will have drained by the end of the simulation period
- Maximum water levels resulting from rainfall-runoff (modelled depths) and claypan storage (contour) are unlikely to occur simultaneously as they will be driven by different magnitude and duration rainfall events.
- Outflow water depths along the north-east of the model boundary are not valid.

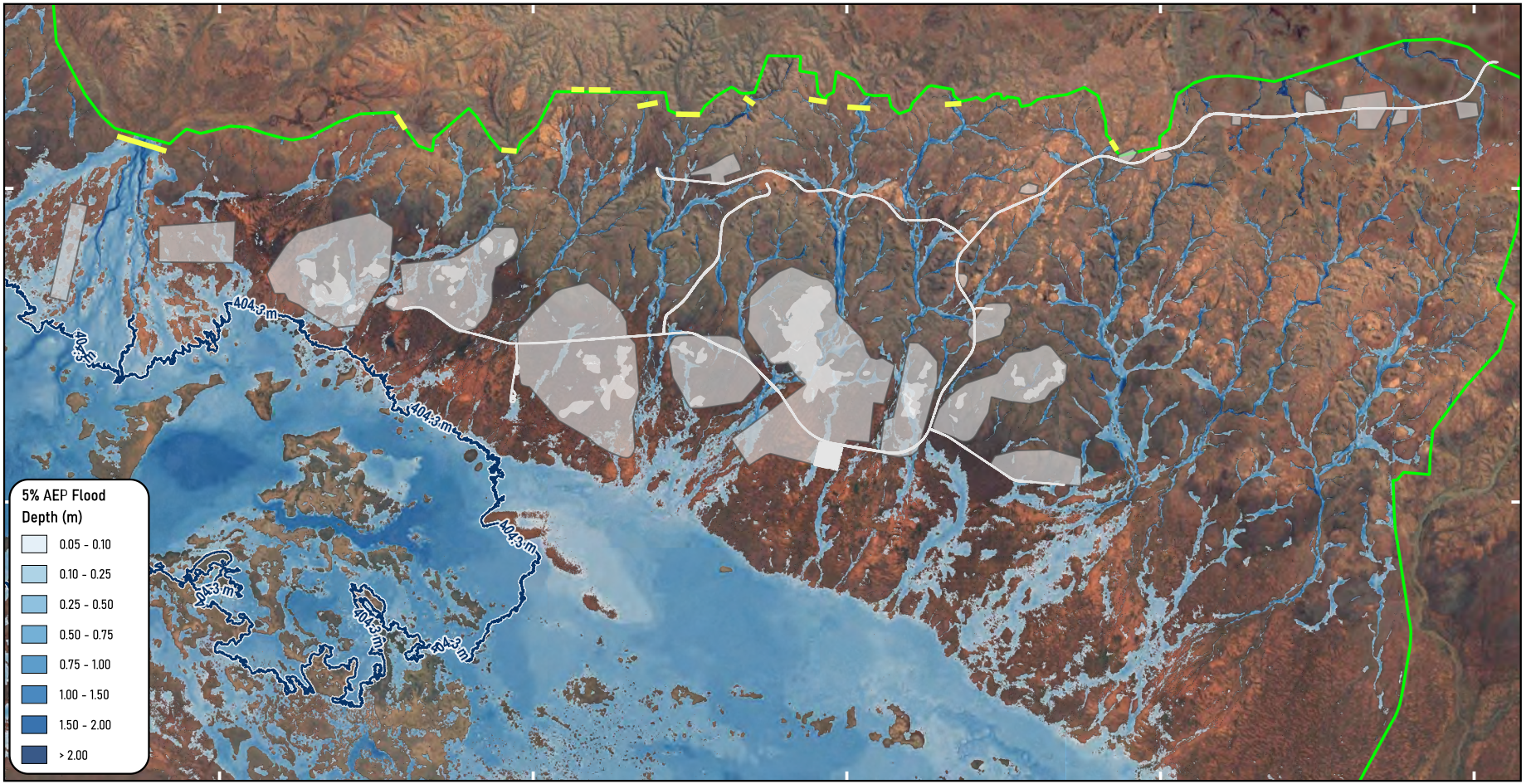
Data sources: Background Image: Base map and data from Google. © https://www.google.com/



P:\777\A.GIS\Workspaces\A9b Figures\Appendix A.qgz, Figure A9 – 5% Depth (dart)

AQ2

Hydrology Figure A9
Baseline Scenario
5% AEP Flood Depth



N

2 4 km

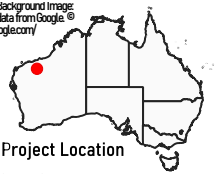
GDA94 / MGA zone 50

Legend

- Model Inflow
- Rain On Grid Model Boundary
- 5% AEP Claypan Level (404.3 mRL)
- Proposed Haul Road
- Surface Water Containment Area
- Proposed Pit Footprint (MDE_LOM_20)

- Predicted maximum flood depths are from the simulation period of a 2D HEC RAS model developed using LIDAR data from 2023, excluding depths less than 0.05m.
- The purpose of the model was to simulate hydrological conditions within, and immediately downstream of, mine development areas associated with the Mulga Downs Project.
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- Outflow water depths along the north-east of the model boundary are not valid.

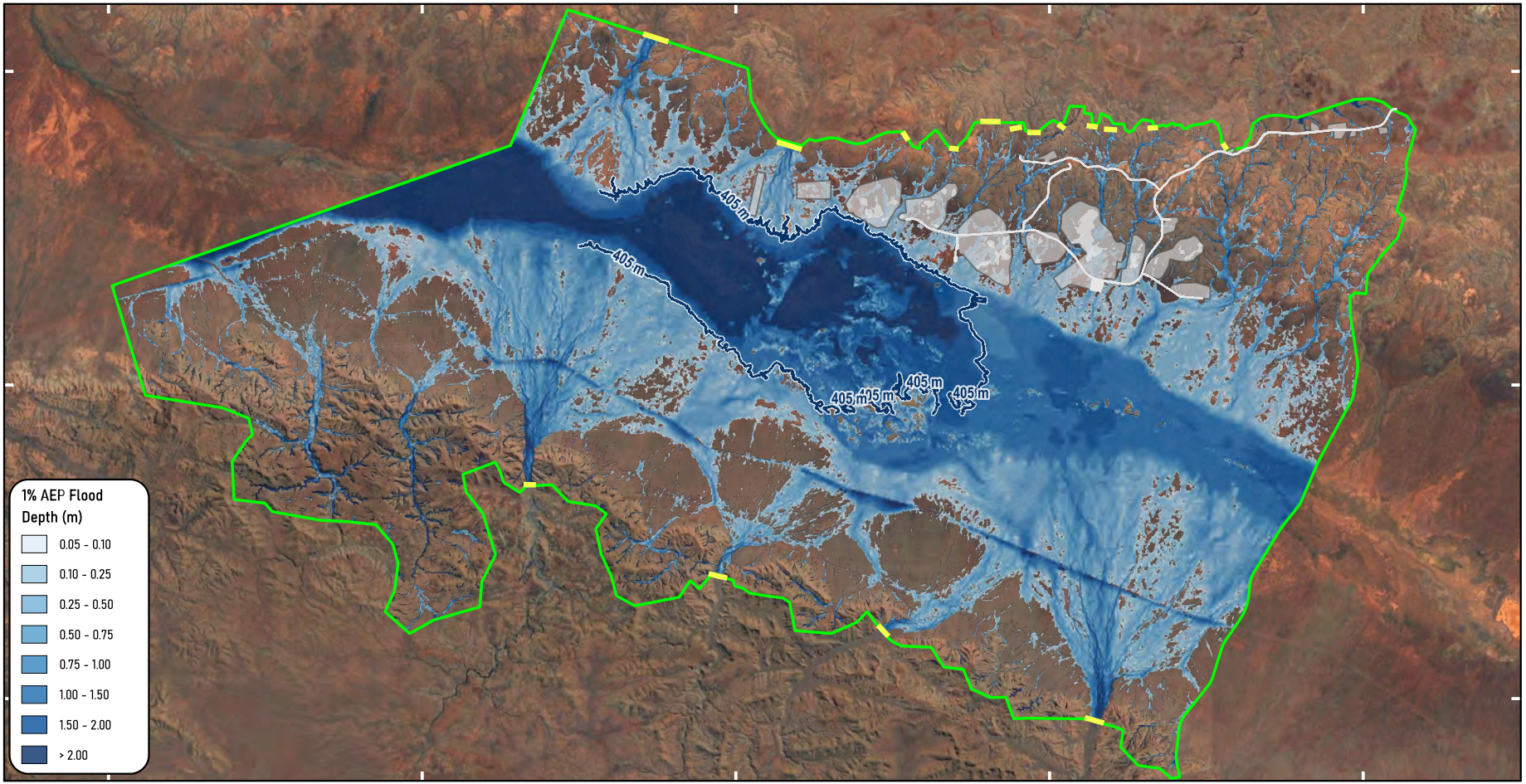
Data sources: Background Image: Base map and data from Google. © https://www.google.com/



J:\771\A.GIS\Workspaces\492b Figures\Appendix A.qgz, Figure A10 - 5% Depth (plan1)

AQ2

Hydrology Figure A10
Baseline Scenario
5% AEP Flood Depth



N

4 8 km

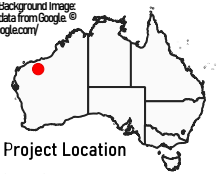
GDA94 / MGA zone 50

Legend

- Model Inflow
- Rain On Grid Model Boundary
- 1% AEP Claypan Level (405 mRL)
- Proposed Haul Road
- Surface Water Containment Area
- Proposed Pit Footprint (MDE_LOM_20)

- Predicted maximum flood depths are from the simulation period of a 2D HEC RAS model developed using LIDAR data from 2023, excluding depths less than 0.05m.
- The purpose of the model was to simulate hydrological conditions within, and immediately downstream of, mine development areas associated with the Mulga Downs Project.
- Inflow hydrographs were input around the boundary of the model and rain-on-grid calculations used to simulate runoff across the model domain.
- Flood depths upstream of the inflow boundary conditions are not valid.
- Depths of ponded water within the valley floor (e.g., in the claypans) are likely to be underpredicted as not all runoff from within the model will have drained by the end of the simulation period
- Maximum water levels resulting from rainfall-runoff (modelled depths) and claypan storage (contour) are unlikely to occur simultaneously as they will be driven by different magnitude and duration rainfall events.
- Outflow water depths along the north-east of the model boundary are not valid.

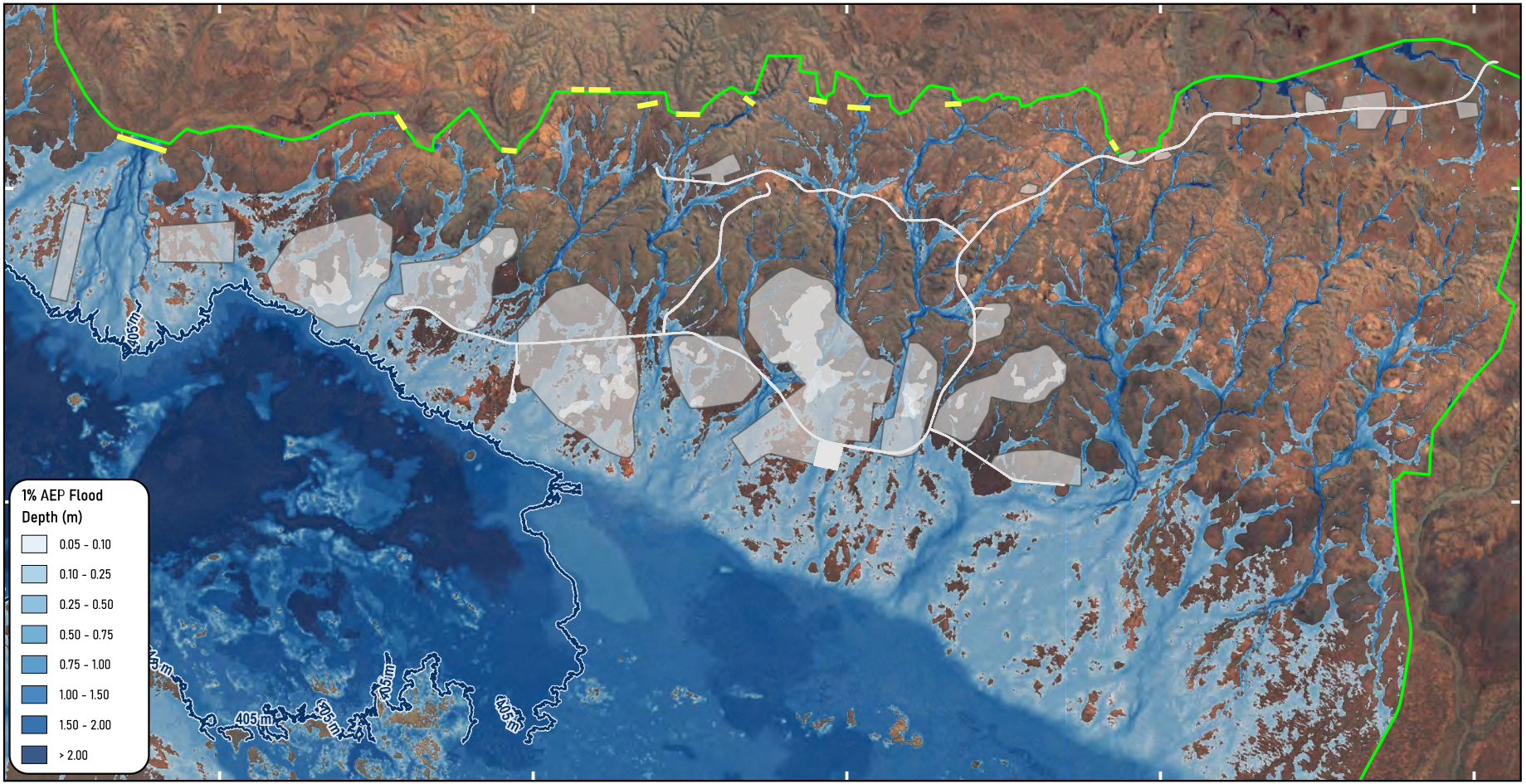
Data sources: Background Image: Base map and data from Google. © https://www.google.com/



P:\177\A.GIS\Workspaces\A92b Figures\Appendix A.qgz, Figure A11 - 1% Depth (alert)

AQ2

Hydrology Figure A11
Baseline Scenario
1% AEP Flood Depth



N

2 4 km

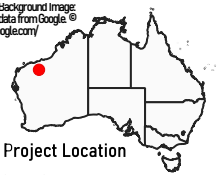
GDA94 / MGA zone 50

Legend

- Model Inflow
- Rain On Grid Model Boundary
- 1% AEP Claypan Level (405 mRL)
- Proposed Haul Road
- Surface Water Containment Area
- Proposed Pit Footprint (MDE_LOM_20)

- Predicted maximum flood depths are from the simulation period of a 2D HEC RAS model developed using LIDAR data from 2023, excluding depths less than 0.05m.
- The purpose of the model was to simulate hydrological conditions within, and immediately downstream of, mine development areas associated with the Mulga Downs Project.
- Inflow hydrographs were input around the boundary of the model and rain-on-grid calculations used to simulate runoff across the model domain.
- Flood depths upstream of the inflow boundary conditions are not valid.
- Depths of ponded water within the valley floor (e.g., in the claypans) are likely to underpredicted as not all runoff from within the model will have drained by the end of the simulation period
- Maximum water levels resulting from rainfall-runoff (modelled depths) and claypan storage (contour) are unlikely to occur simultaneously as they will be driven by different magnitude and duration rainfall events.
- Outflow water depths along the north-east of the model boundary are not valid.

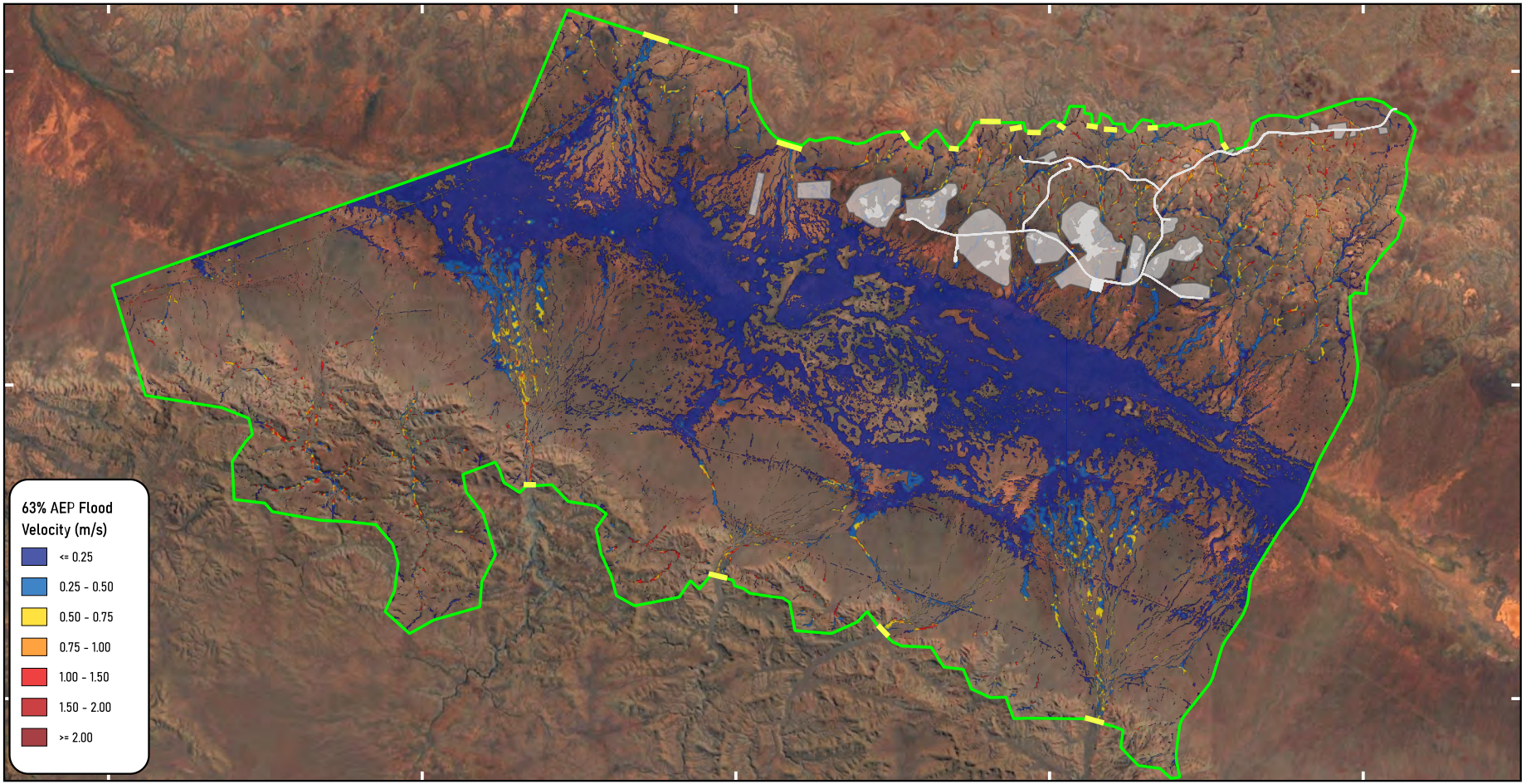
Data sources: Background Image: Base map and data from Google. © https://www.google.com/



P:\777\A.GIS\Workspaces\692b Figures\Appendix A.qgz, Figure A12 - 1% Depth (plan1)

AQ2

Hydrology Figure A12
Baseline Scenario
1% AEP Flood Depth



N

4 8 km

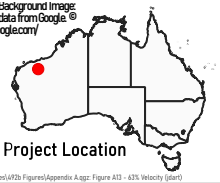
GDA94 / MGA zone 50

Legend

- Model Inflow
- Rain On Grid Model Boundary
- Proposed Haul Road
- Surface Water Containment Area
- Proposed Pit Footprint (MDE_LOM_20)

- Predicted maximum flood velocities are from the simulation period of a 2D HEC RAS model developed using LIDAR data from 2023
- The purpose of the model was to simulate hydrological conditions within, and immediately downstream of, mine development areas associated with the Mulga Downs Project.
- Inflow hydrographs were input around the boundary of the model and rain-on-grid calculations used to simulate runoff across the model domain.
- Flood velocities upstream of the inflow boundary conditions are not valid
- The claypan extent has been output from water balance modelling.

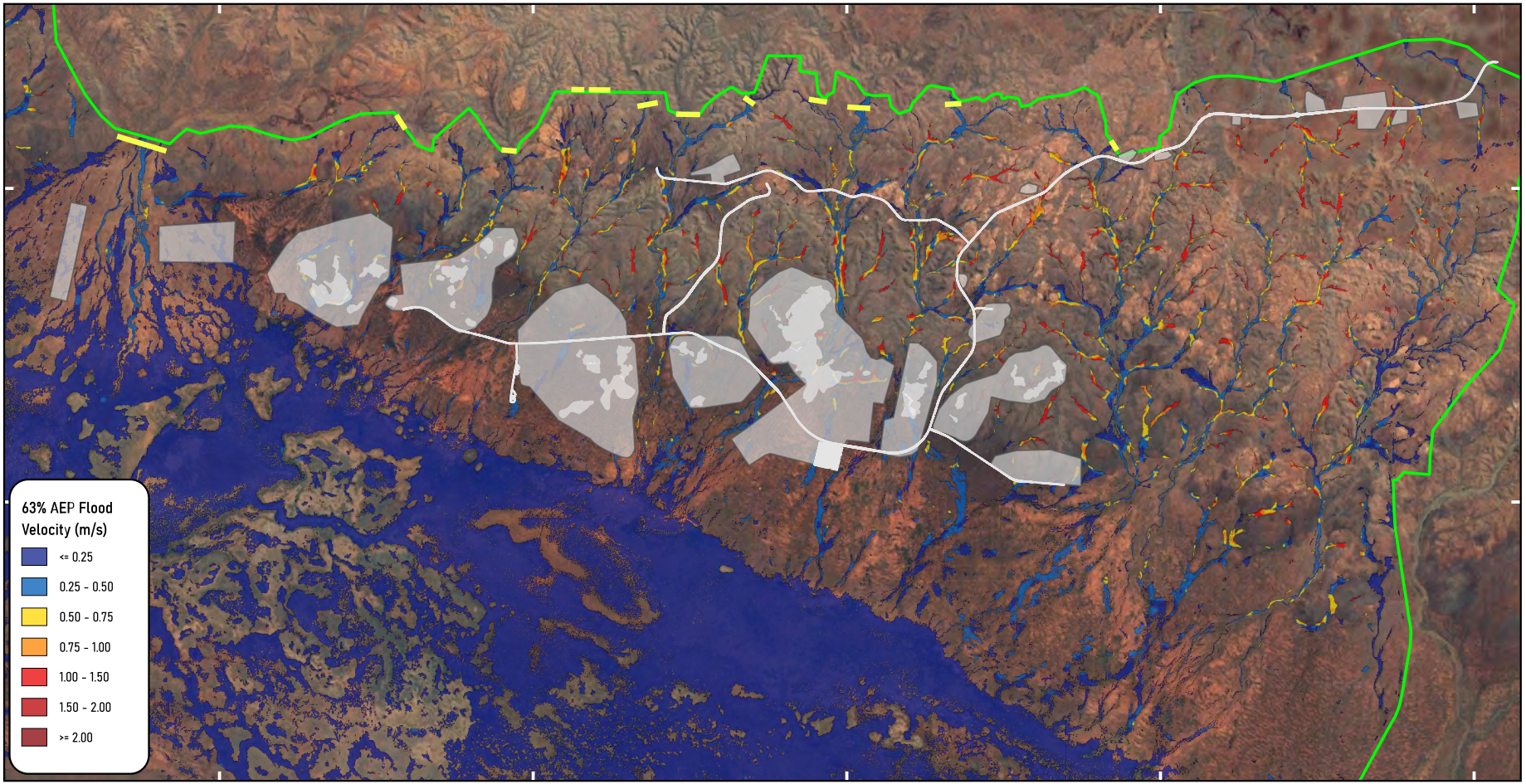
Data sources: Background Image: Base map and data from Google. © https://www.google.com/



P:\7711\GIS\Workspaces\692b Figures\Appendix A.qgz, Figure A13 - 63% Velocity (plan)

AQ2

Hydrology Figure A13
Baseline Scenario
63% AEP Flood Velocity



N

2 4 km

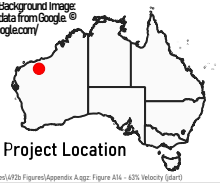
GDA94 / MGA zone 50

Legend

- Model Inflow
- Rain On Grid Model Boundary
- Proposed Haul Road
- Surface Water Containment Area
- Proposed Pit Footprint (MDE_LOM_20)

- Predicted maximum flood velocities are from the simulation period of a 2D HEC RAS model developed using LIDAR data from 2023
- The purpose of the model was to simulate hydrological conditions within, and immediately downstream of, mine development areas associated with the Mulga Downs Project.
- Inflow hydrographs were input around the boundary of the model and rain-on-grid calculations used to simulate runoff across the model domain.
- Flood velocities upstream of the inflow boundary conditions are not valid
- The claypan extent has been output from water balance modelling.

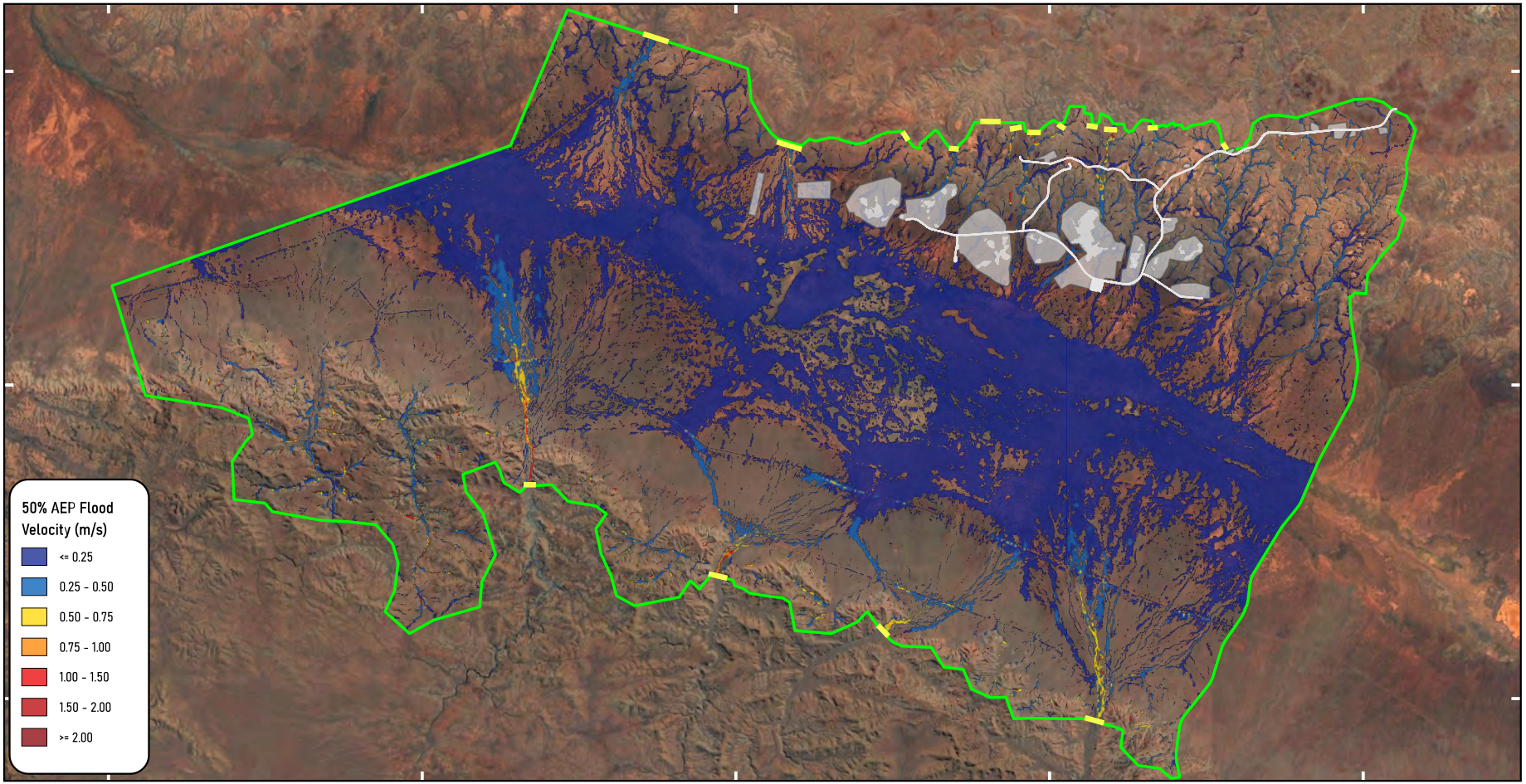
Data sources: Background Image: Base map and data from Google. © https://www.google.com/



P:\777\A.GIS\Workspaces\692b Figures\Appendix A.qgz, Figure A14 - 63% Velocity (plan1)

AQ2

Hydrology Figure A14
Baseline Scenario
63% AEP Flood Velocity



N

4 8 km

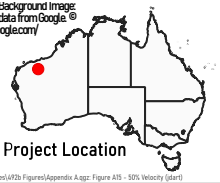
GDA94 / MGA zone 50

Legend

- Model Inflow
- Rain On Grid Model Boundary
- Proposed Haul Road
- Surface Water Containment Area
- Proposed Pit Footprint (MDE_LOM_20)

- Predicted maximum flood velocities are from the simulation period of a 2D HEC RAS model developed using LIDAR data from 2023
- The purpose of the model was to simulate hydrological conditions within, and immediately downstream of, mine development areas associated with the Mulga Downs Project.
- Inflow hydrographs were input around the boundary of the model and rain-on-grid calculations used to simulate runoff across the model domain.
- Flood velocities upstream of the inflow boundary conditions are not valid
- The claypan extent has been output from water balance modelling.

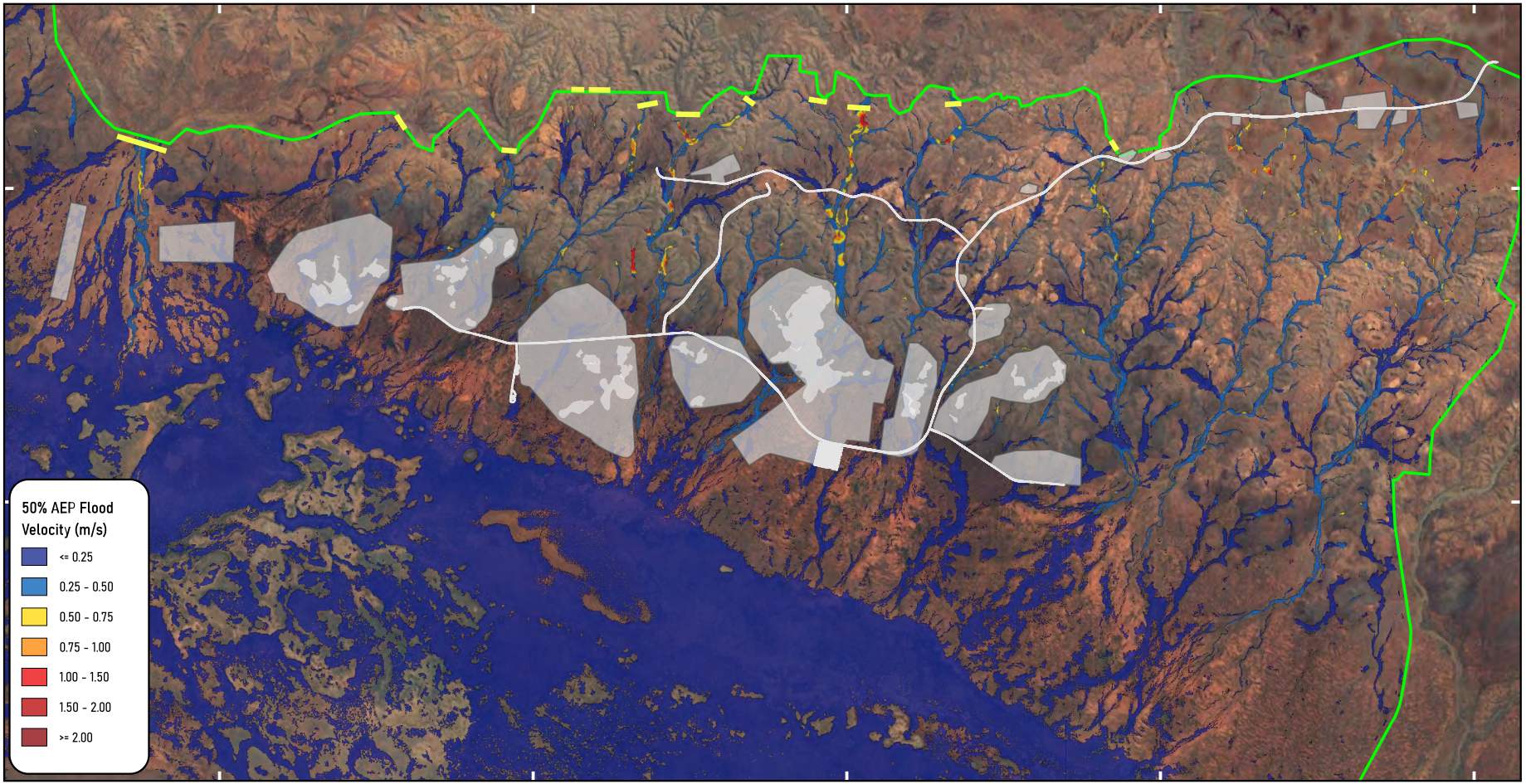
Data sources: Background Image: Base map and data from Google. © https://www.google.com/



P:\7711\GIS\Workspaces\A92b Figures\Appendix A.qgz, Figure A15 - 50% Velocity (plan)

AQ2

Hydrology Figure A15
Baseline Scenario
50% AEP Flood Velocity



N

2 4 km

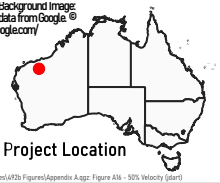
GDA94 / MGA zone 50

Legend

- Model Inflow
- Rain On Grid Model Boundary
- Proposed Haul Road
- Surface Water Containment Area
- Proposed Pit Footprint (MDE_LOM_20)

- Predicted maximum flood velocities are from the simulation period of a 2D HEC RAS model developed using LIDAR data from 2023
- The purpose of the model was to simulate hydrological conditions within, and immediately downstream of, mine development areas associated with the Mulga Downs Project.
- Inflow hydrographs were input around the boundary of the model and rain-on-grid calculations used to simulate runoff across the model domain.
- Flood velocities upstream of the inflow boundary conditions are not valid
- The claypan extent has been output from water balance modelling.

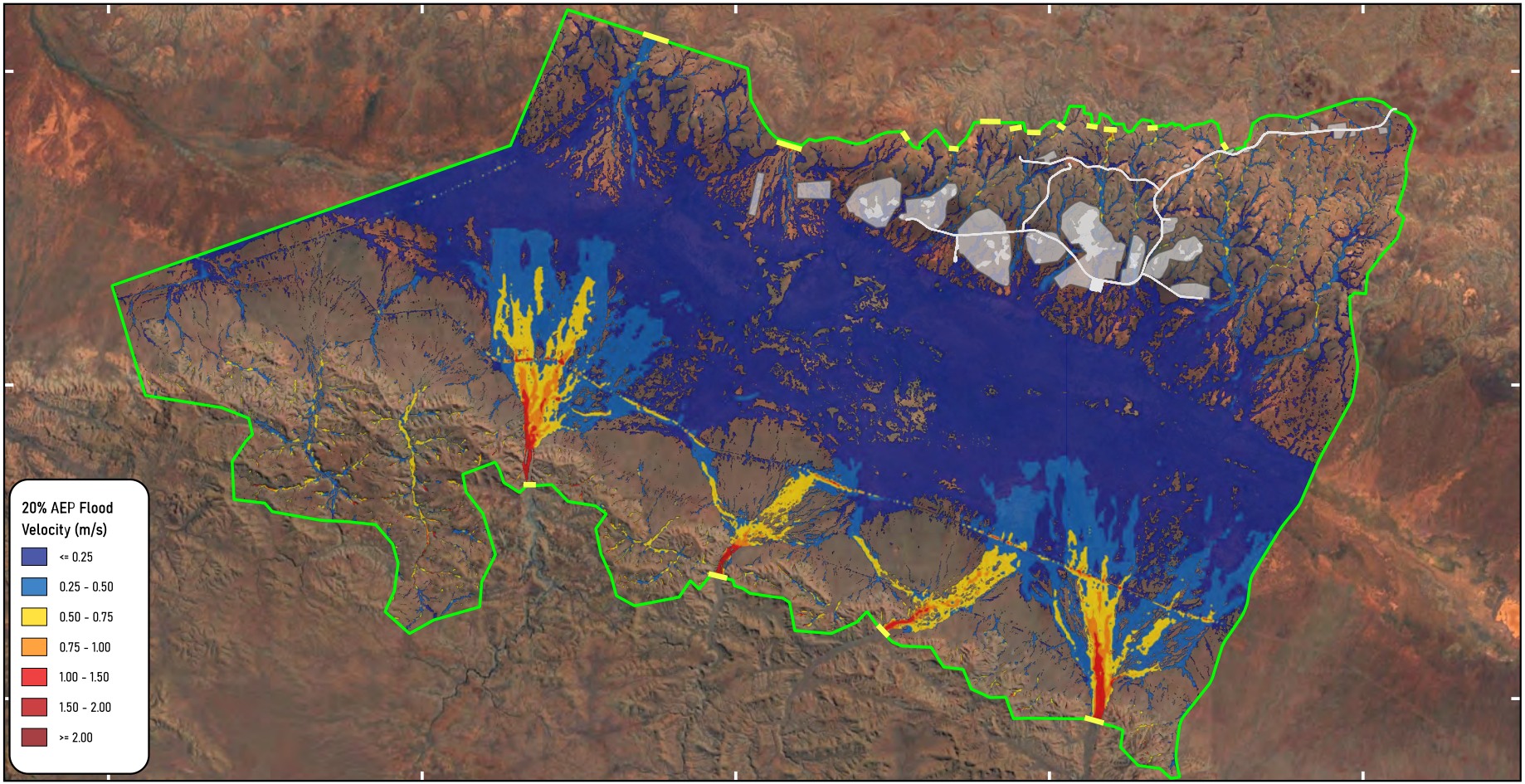
Data sources: Background Image: Base map and data from Google. © https://www.google.com/



P:\777\A.GIS\Workspaces\692b Figures\Appendix A.qgz, Figure A16 - 50% Velocity (plan1)

AQ2

Hydrology Figure A16
Baseline Scenario
50% AEP Flood Velocity



N

4 8 km

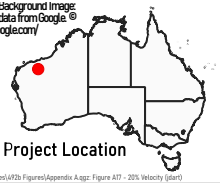
GDA94 / MGA zone 50

Legend

- Model Inflow
- Rain On Grid Model Boundary
- Proposed Haul Road
- Surface Water Containment Area
- Proposed Pit Footprint (MDE_LOM_20)

- Predicted maximum flood velocities are from the simulation period of a 2D HEC RAS model developed using LIDAR data from 2023
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- Inflow hydrographs were input around the boundary of the model and rain-on-grid calculations used to simulate runoff across the model domain.
- Flood velocities upstream of the inflow boundary conditions are not valid
- The claypan extent has been output from water balance modelling.

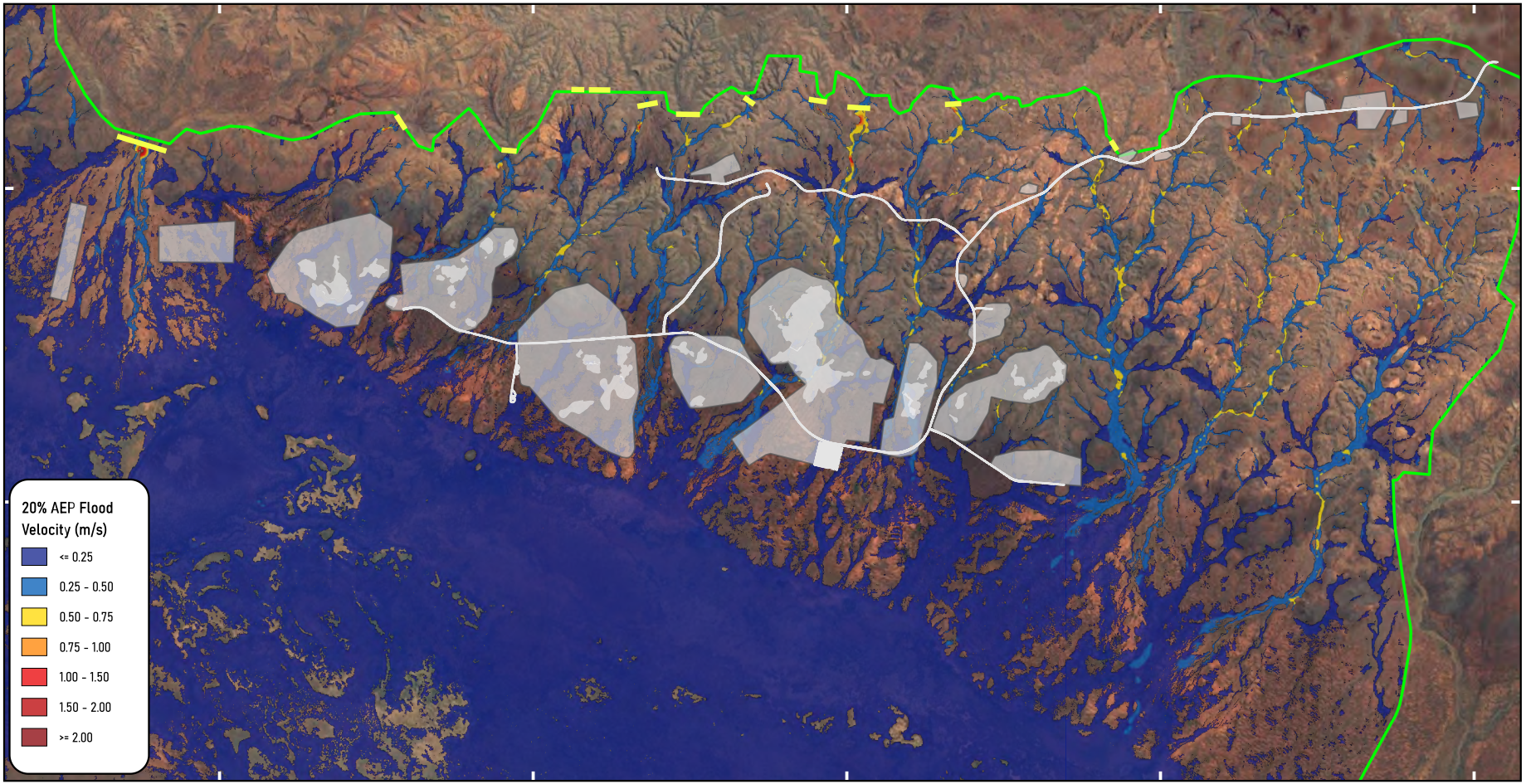
Data sources: Background Image: Base map and data from Google. © https://www.google.com/



P:\177\ILA\GIS\Workspaces\A92b Figures\Appendix A.qgz, Figure A17 - 20% Velocity (plan)

AQ2

Hydrology Figure A17
Baseline Scenario
20% AEP Flood Velocity



N

2 4 km

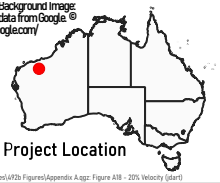
GDA94 / MGA zone 50

Legend

- Model Inflow
- Rain On Grid Model Boundary
- Proposed Haul Road
- Surface Water Containment Area
- Proposed Pit Footprint (MDE_LOM_20)

- Predicted maximum flood velocities are from the simulation period of a 2D HEC RAS model developed using LIDAR data from 2023
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- Flood velocities upstream of the inflow boundary conditions are not valid
- The claypan extent has been output from water balance modelling.

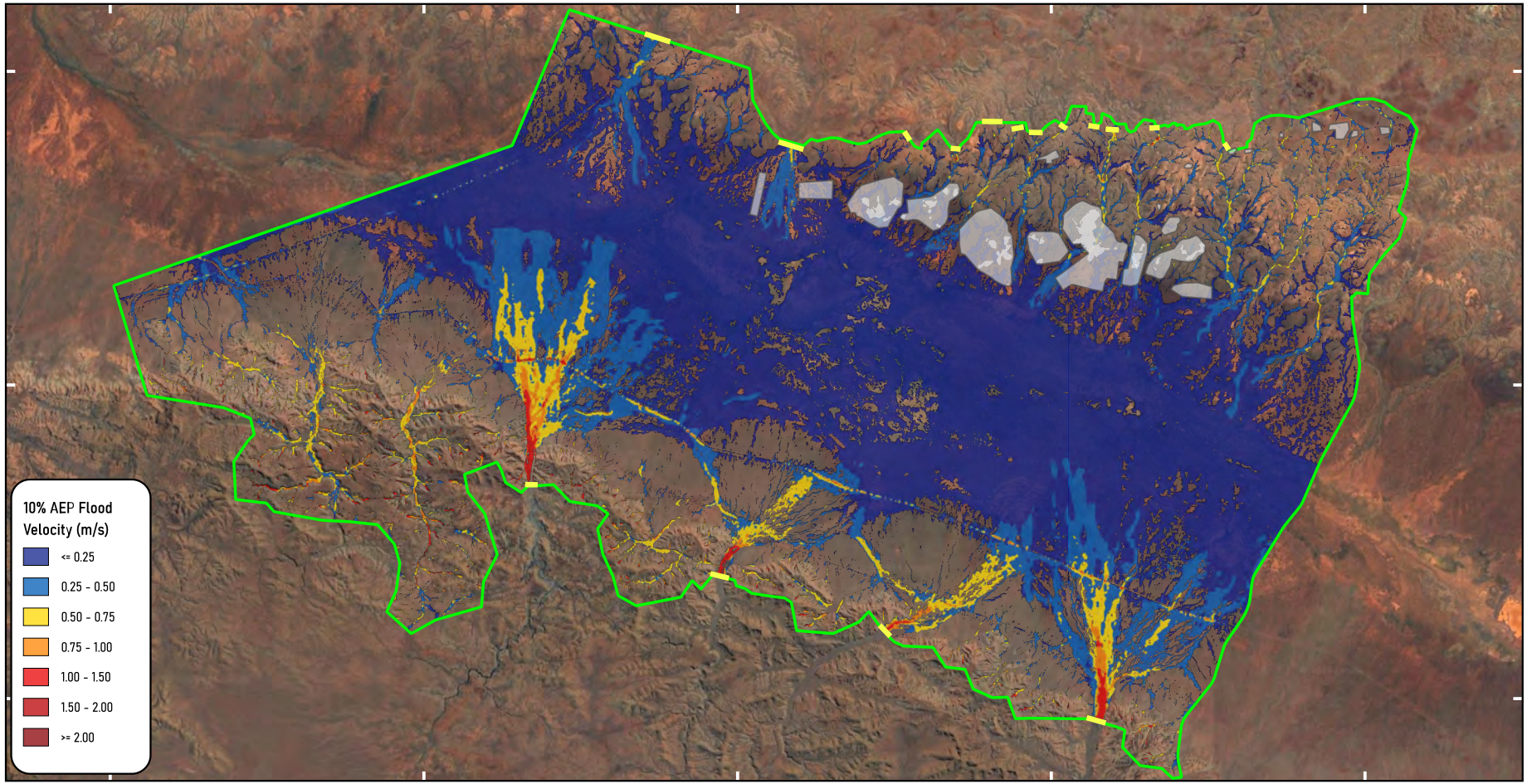
Data sources: Background Image: Base map and data from Google. © https://www.google.com/



P:\777\A.GIS\Workspaces\692b Figures\Appendix A.qgz, Figure A18 - 20% Velocity (plan1)

AQ2

Hydrology Figure A18
Baseline Scenario
20% AEP Flood Velocity



N

4 8 km

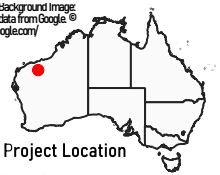
GDA94 / MGA zone 50

Legend

- Model Inflow
- Rain On Grid Model Boundary
- Proposed Haul Road
- Surface Water Containment Area
- Proposed Pit Footprint (MDE_LOM_20)

- Predicted maximum flood velocities are from the simulation period of a 2D HEC RAS model developed using LIDAR data from 2023
- The purpose of the model was to simulate hydrological conditions within, and immediately downstream of, mine development areas associated with the Mulga Downs Project.
- Inflow hydrographs were input around the boundary of the model and rain-on-grid calculations used to simulate runoff across the model domain.
- Flood velocities upstream of the inflow boundary conditions are not valid
- The claypan extent has been output from water balance modelling.

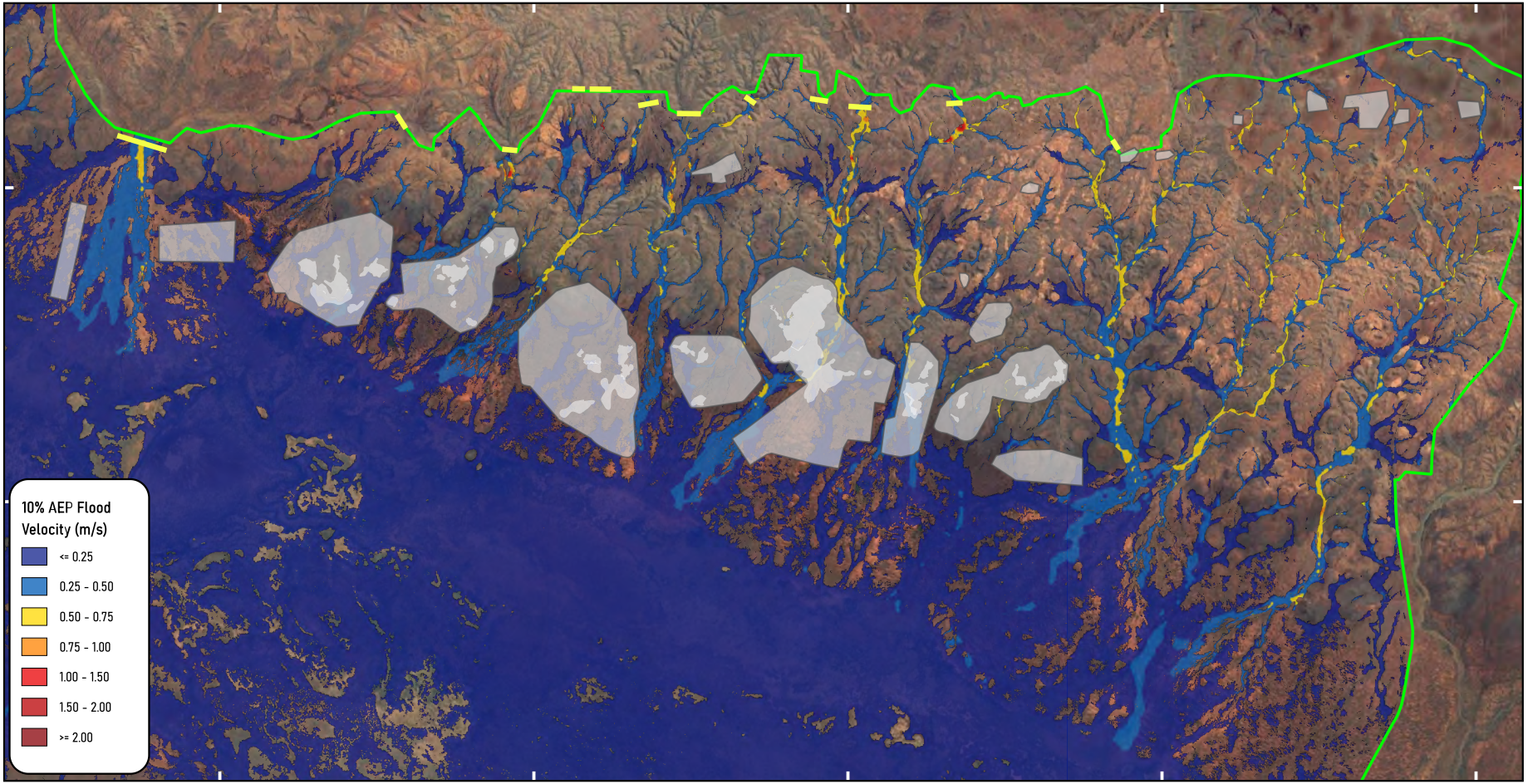
Data sources: Background Image: Base map and data from Google. © https://www.google.com/



P:\177\ILA\GIS\Workspaces\A92b Figures\Appendix A.qgz, Figure A19 - 10% Velocity (clean)

AQ2

Hydrology Figure A19
Baseline Scenario
10% AEP Flood Velocity



N

2 4 km

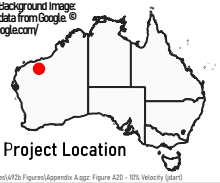
GDA94 / MGA zone 50

Legend

- Model Inflow
- Rain On Grid Model Boundary
- Proposed Haul Road
- Surface Water Containment Area
- Proposed Pit Footprint (MDE_LOM_20)

- Predicted maximum flood velocities are from the simulation period of a 2D HEC RAS model developed using LIDAR data from 2023
- The purpose of the model was to simulate hydrological conditions within, and immediately downstream of, mine development areas associated with the Mulga Downs Project.
- Inflow hydrographs were input around the boundary of the model and rain-on-grid calculations used to simulate runoff across the model domain.
- Flood velocities upstream of the inflow boundary conditions are not valid
- The claypan extent has been output from water balance modelling.

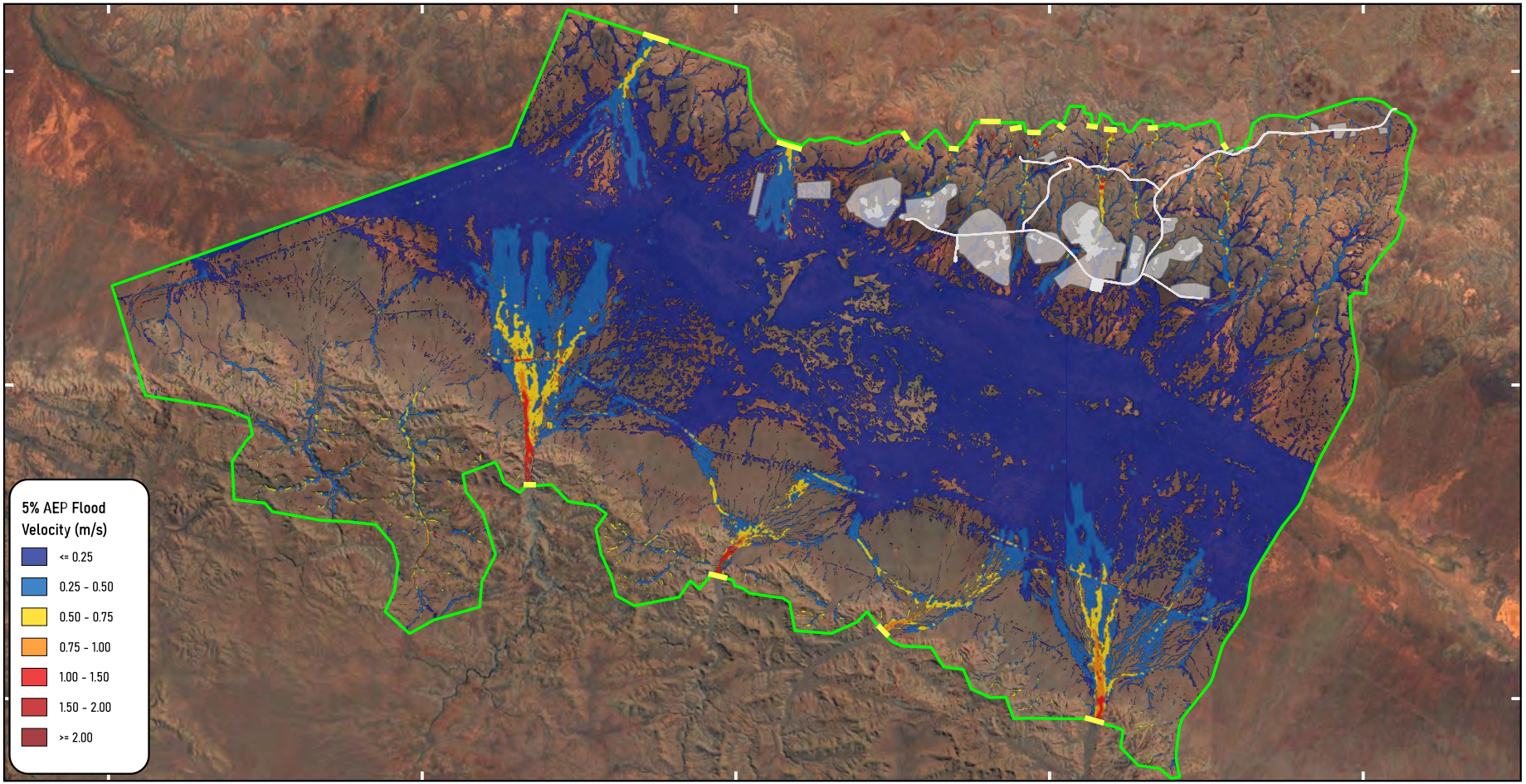
Data sources: Background Image: Base map and data from Google. © https://www.google.com/



P:\7711\A.GIS\Workspaces\692b Figures\Appendix A.qgz, Figure A20 - 10% Velocity (plan1)

AQ2

Hydrology Figure A20
Baseline Scenario
10% AEP Flood Velocity



N

4 8 km

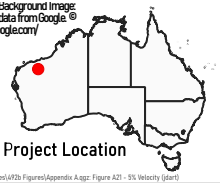
GDA94 / MGA zone 50

Legend

- Model Inflow
- Rain On Grid Model Boundary
- Proposed Haul Road
- Surface Water Containment Area
- Proposed Pit Footprint (MDE_LOM_20)

- Predicted maximum flood velocities are from the simulation period of a 2D HEC RAS model developed using LIDAR data from 2023
- The purpose of the model was to simulate hydrological conditions within, and immediately downstream of, mine development areas associated with the Mulga Downs Project.
- Inflow hydrographs were input around the boundary of the model and rain-on-grid calculations used to simulate runoff across the model domain.
- Flood velocities upstream of the inflow boundary conditions are not valid
- The claypan extent has been output from water balance modelling.

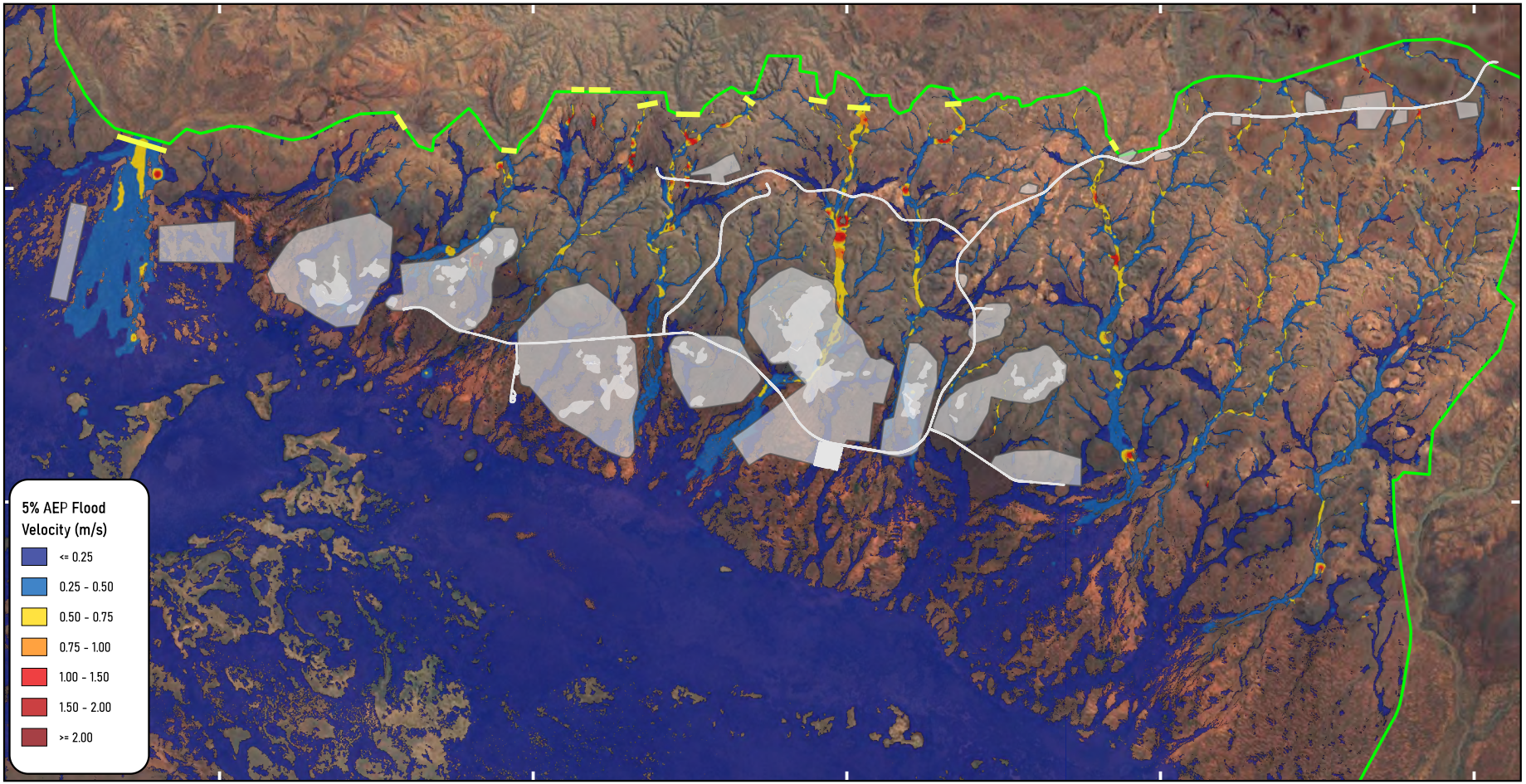
Data sources: Background Image: Base map and data from Google. © https://www.google.com/



P:\7711\GIS\Workspaces\A92b Figures\Appendix A.qgz: Figure A21 - 5% Velocity (plan)

AQ2

Hydrology Figure A21
Baseline Scenario
5% AEP Flood Velocity



N

2 4 km

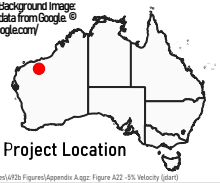
GDA94 / MGA zone 50

Legend

- Model Inflow
- Rain On Grid Model Boundary
- Proposed Haul Road
- Surface Water Containment Area
- Proposed Pit Footprint (MDE_LOM_20)

- Predicted maximum flood velocities are from the simulation period of a 2D HEC RAS model developed using LIDAR data from 2023
- The purpose of the model was to simulate hydrological conditions within, and immediately downstream of, mine development areas associated with the Mulga Downs Project.
- Inflow hydrographs were input around the boundary of the model and rain-on-grid calculations used to simulate runoff across the model domain.
- Flood velocities upstream of the inflow boundary conditions are not valid
- The claypan extent has been output from water balance modelling.

Data sources: Background Image: Base map and data from Google. © https://www.google.com/



P:\777\A.GIS\Workspaces\692b Figures\Appendix A.qgz, Figure A22 - 5% Velocity (plan)

AQ2

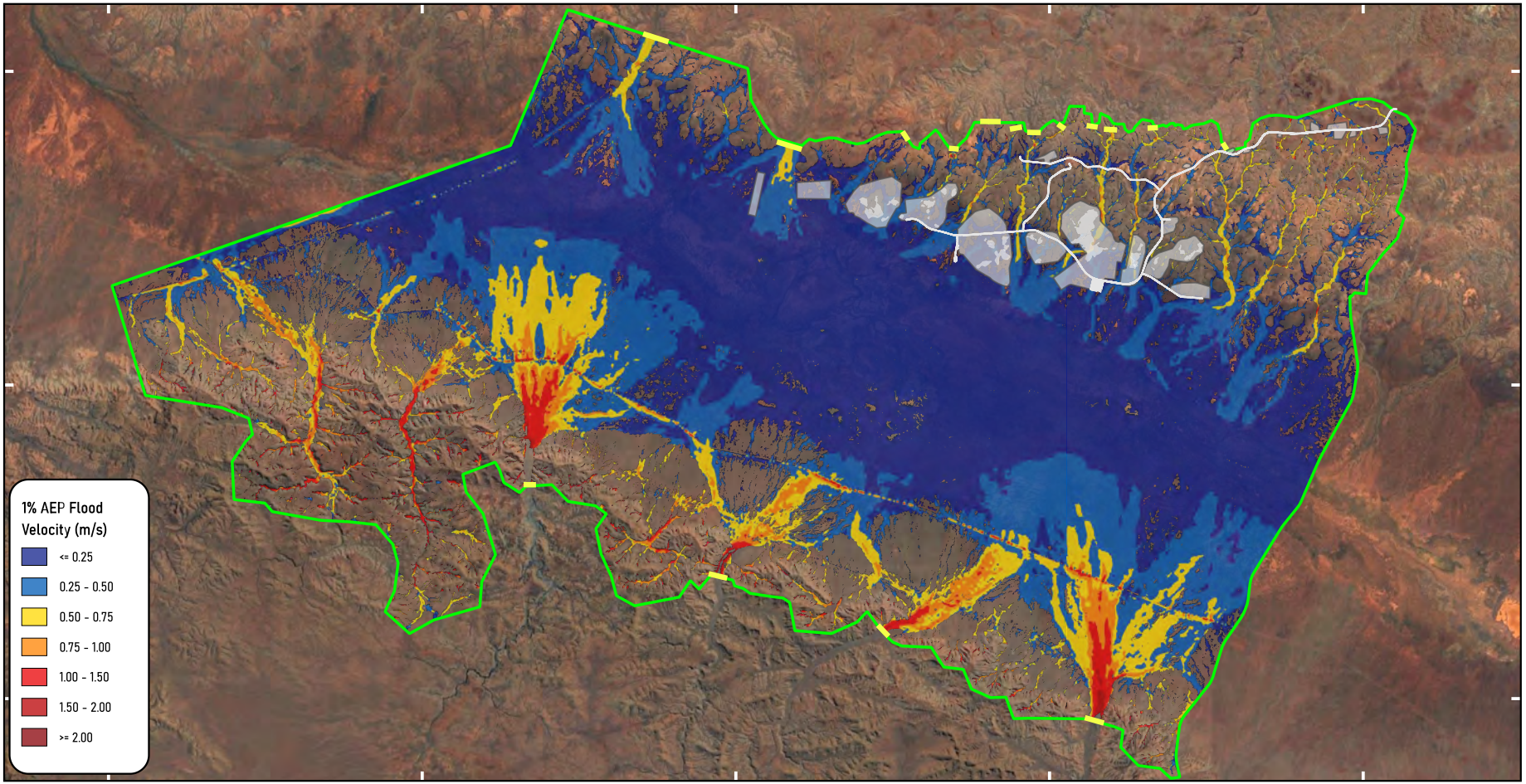
Hydrology Figure A22
Baseline Scenario
5% AEP Flood Velocity

612071E 630073E 648075E 666077E 684079E

7560875N

7542873N

7524871N



612071E 630073E 648075E 666077E 684079E

N

4 8 km

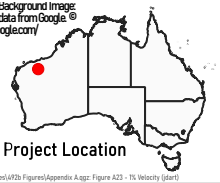
GDA94 / MGA zone 50

Legend

- Model Inflow
- Rain On Grid Model Boundary
- Proposed Haul Road
- Surface Water Containment Area
- Proposed Pit Footprint (MDE_LOM_20)

- Predicted maximum flood velocities are from the simulation period of a 2D HEC RAS model developed using LIDAR data from 2023
- The purpose of the model was to simulate hydrological conditions within, and immediately downstream of, mine development areas associated with the Mulga Downs Project.
- Inflow hydrographs were input around the boundary of the model and rain-on-grid calculations used to simulate runoff across the model domain.
- Flood velocities upstream of the inflow boundary conditions are not valid
- The claypan extent has been output from water balance modelling.

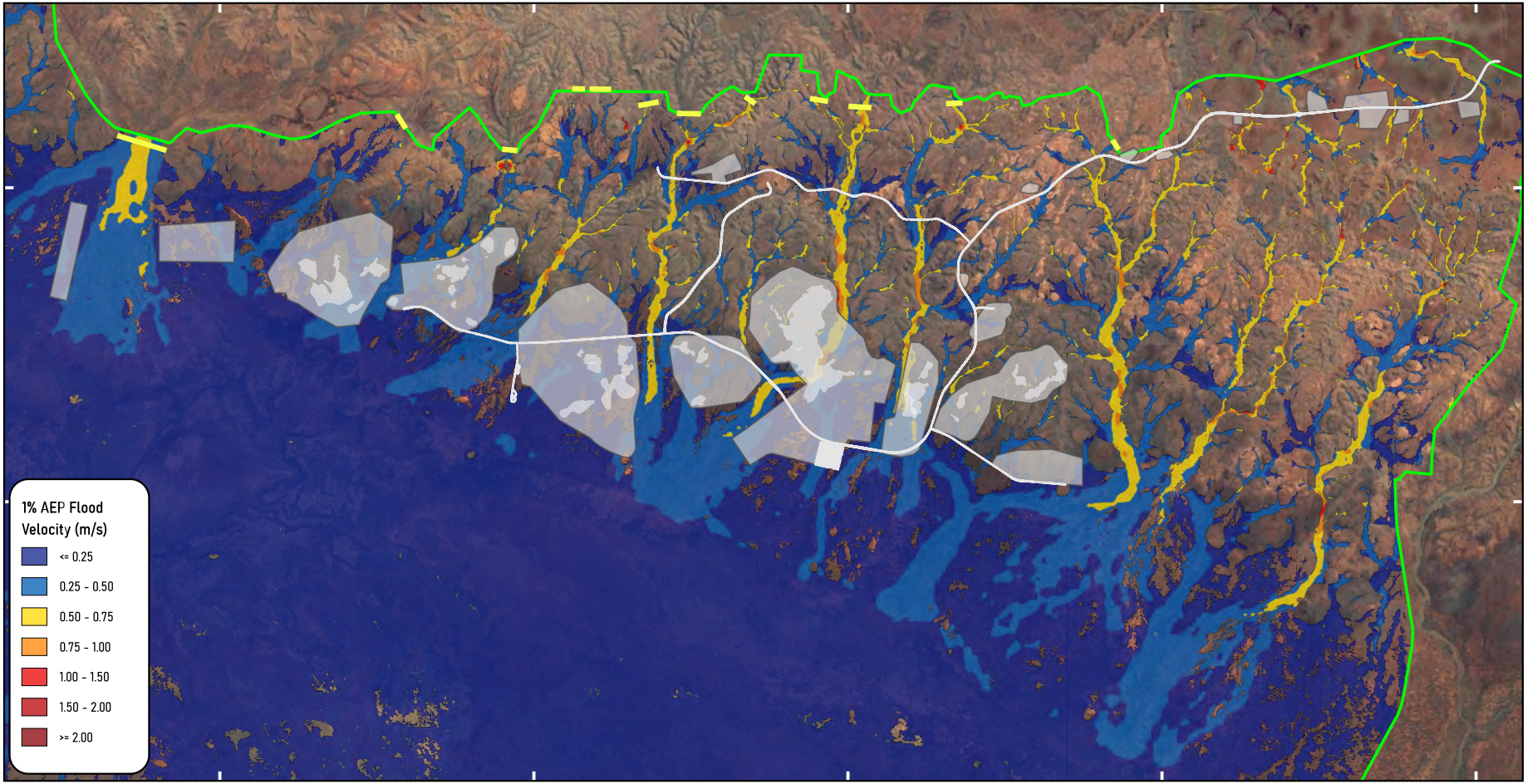
Data sources: Background Image: Base map and data from Google. © https://www.google.com/



P:\7711\A.GIS\Workspaces\A92b Figures\Appendix A.qgz, Figure A23 - 1% Velocity (plan)

AQ2

Hydrology Figure A23
Baseline Scenario
1% AEP Flood Velocity



N

2 4 km

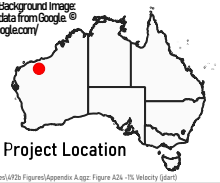
GDA94 / MGA zone 50

Legend

- Model Inflow
- Rain On Grid Model Boundary
- Proposed Haul Road
- Surface Water Containment Area
- Proposed Pit Footprint (MDE_LOM_20)

- Predicted maximum flood velocities are from the simulation period of a 2D HEC RAS model developed using LIDAR data from 2023
- The purpose of the model was to simulate hydrological conditions within, and immediately downstream of, mine development areas associated with the Mulga Downs Project.
- Inflow hydrographs were input around the boundary of the model and rain-on-grid calculations used to simulate runoff across the model domain.
- Flood velocities upstream of the inflow boundary conditions are not valid
- The claypan extent has been output from water balance modelling.

Data sources: Background Image: Base map and data from Google. © https://www.google.com/

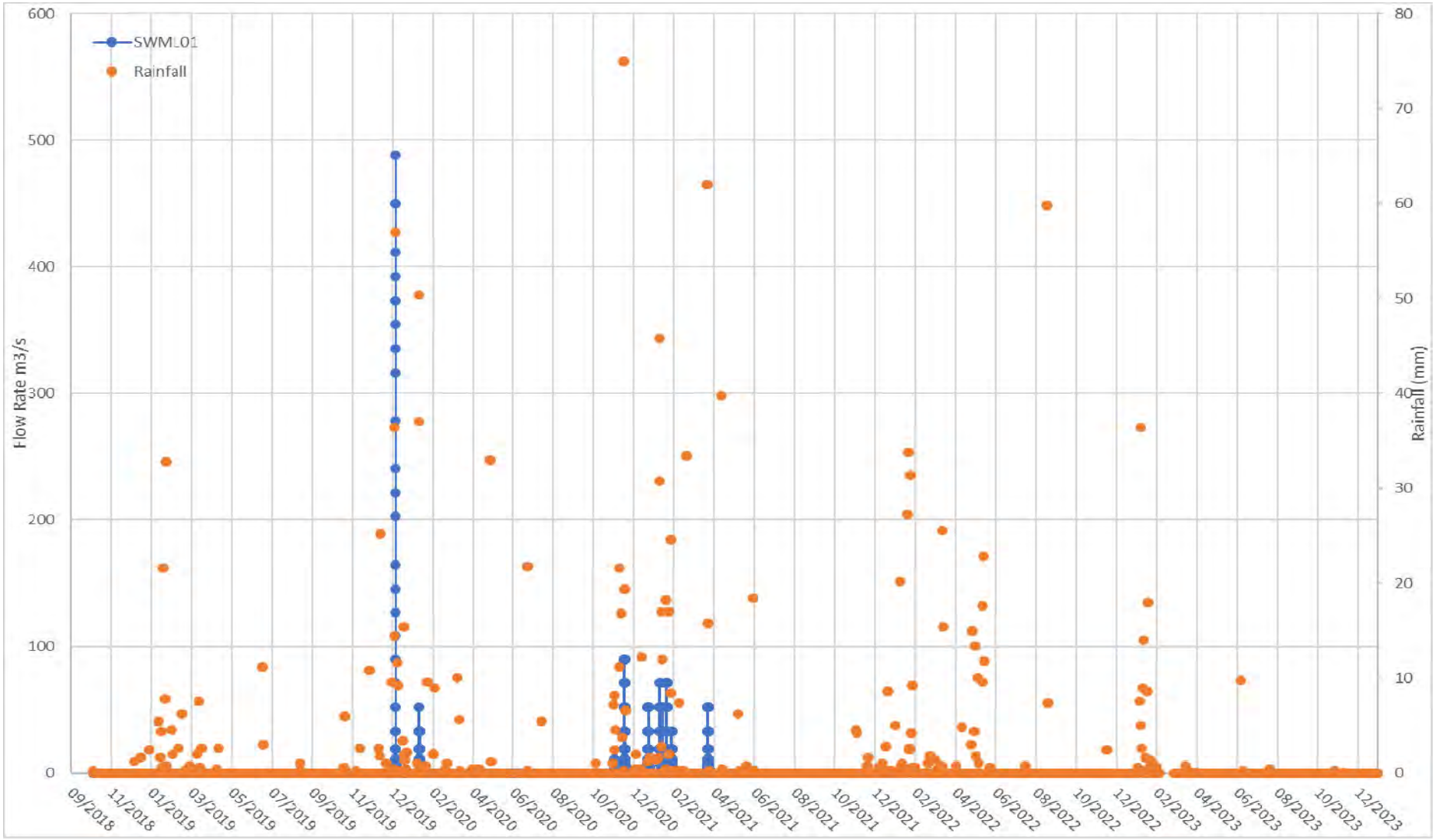


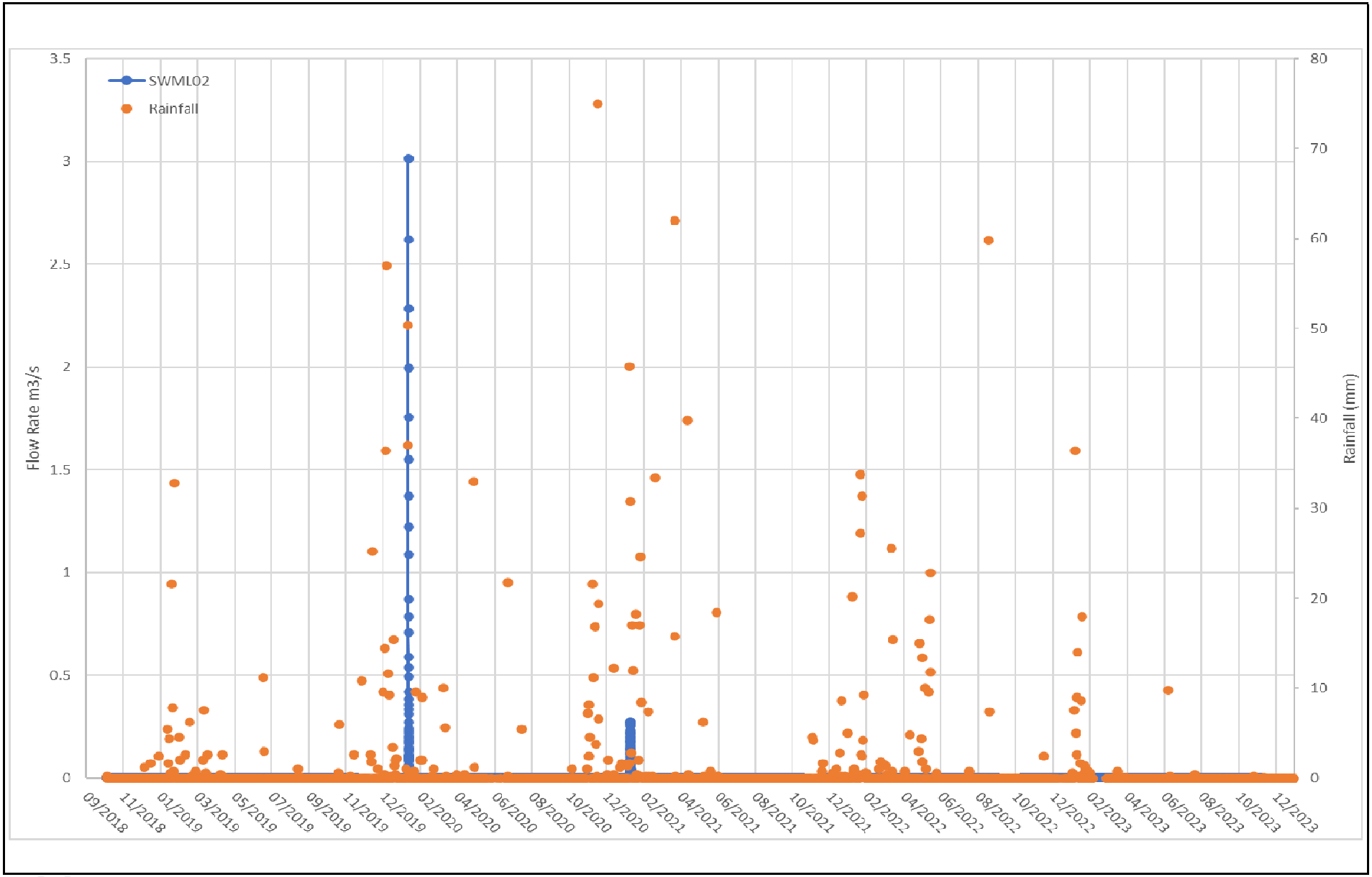
P:\177\A.GIS\Workspaces\A92b Figures\Appendix A.qgz, Figure A24 - 1% Velocity (plan)

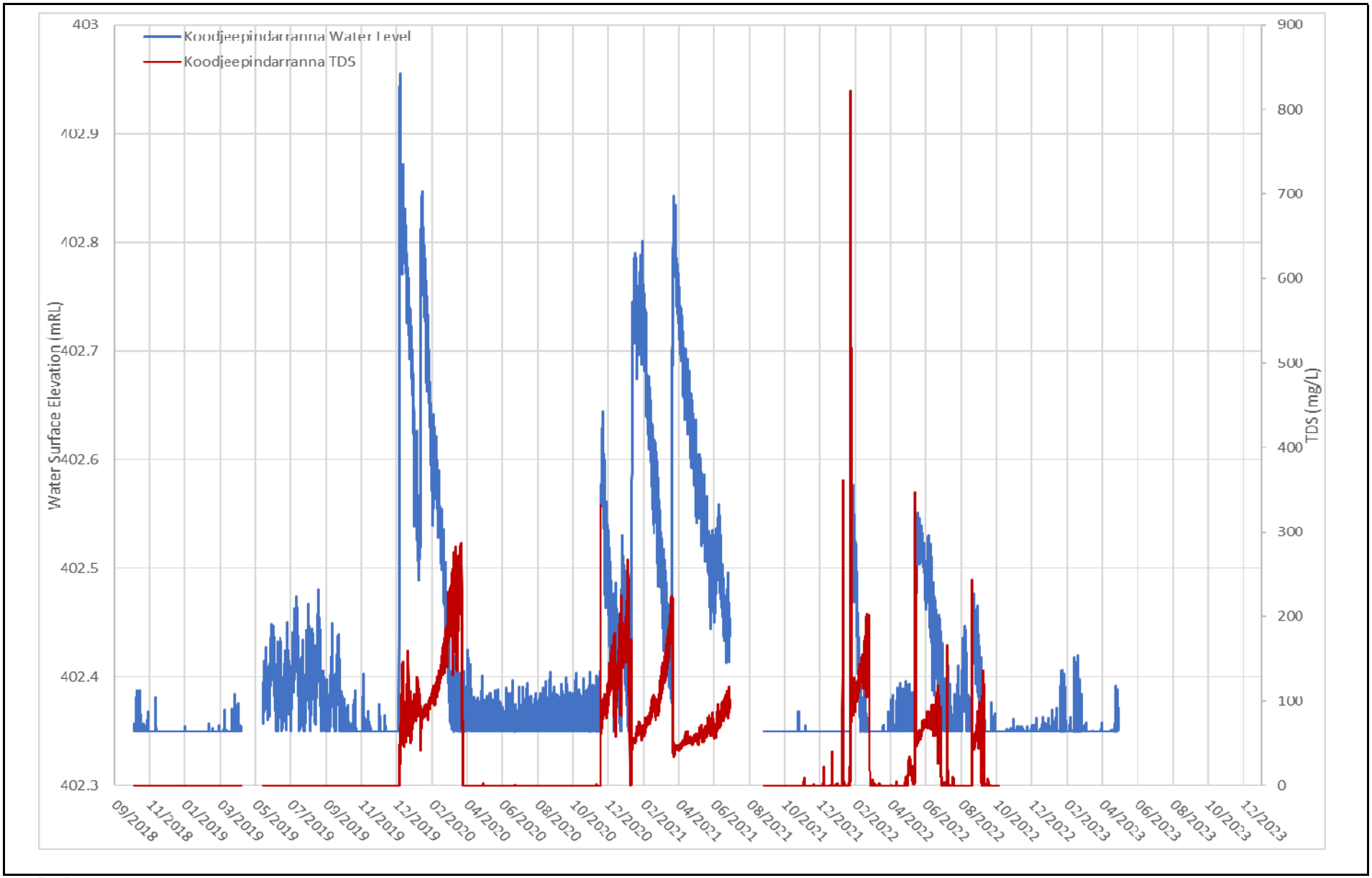
AQ2

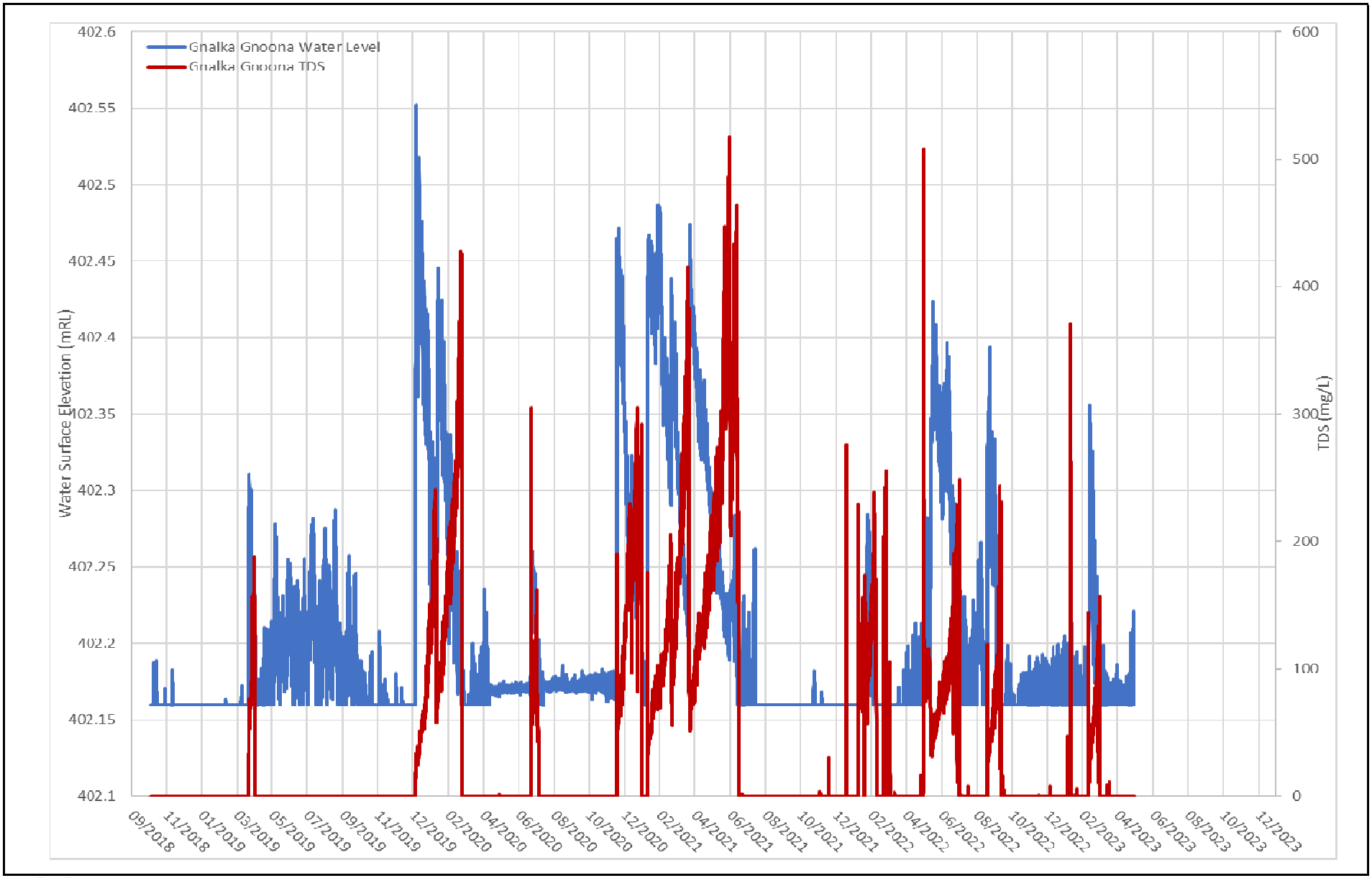
Hydrology Figure A24
Baseline Scenario
1% AEP Flood Velocity

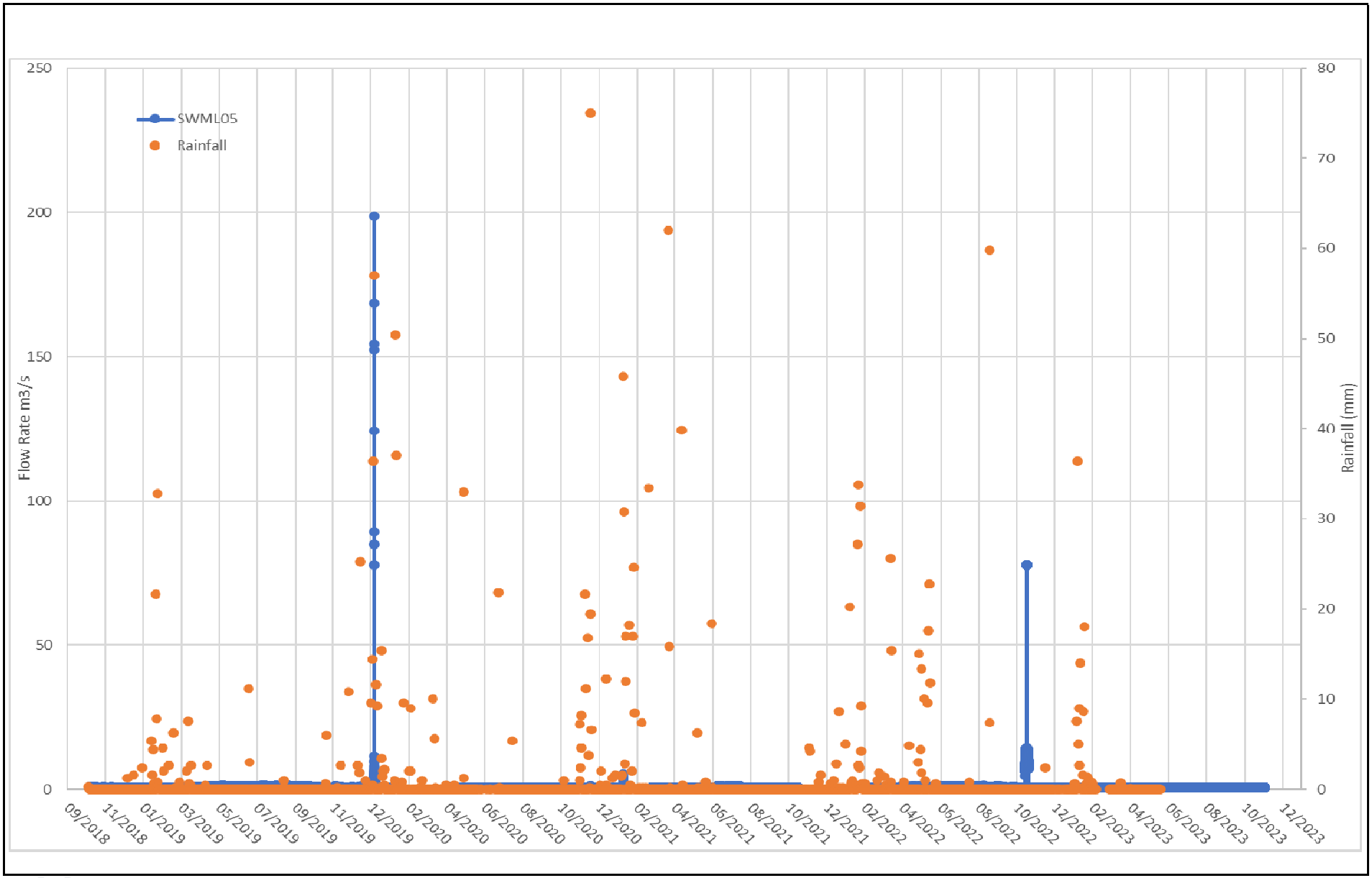
APPENDIX B
CREEK GAUGING DATA HYDROGRAPHS


SWML01
Rainfall
Flow Rate m3/s
Rainfall (mm)
600
500
400
300
200
100
0
80
70
60
50
40
30
20
10
0
09/2018
11/2018
01/2019
03/2019
05/2019
07/2019
09/2019
11/2019
12/2019
02/2020
04/2020
06/2020
08/2020
10/2020
12/2020
02/2021
04/2021
06/2021
08/2021
10/2021
12/2021
02/2022
04/2022
06/2022
08/2022
10/2022
12/2022
02/2023
04/2023
06/2023
08/2023
10/2023
12/2023


SWML02
Rainfall
Flow Rate m3/s
Rainfall (mm)
3.5
3
2.5
2
1.5
1
0.5
0
80
70
60
50
40
30
20
10
0
09/2018
11/2018
01/2019
03/2019
05/2019
07/2019
09/2019
11/2019
12/2019
02/2020
04/2020
06/2020
08/2020
10/2020
12/2020
02/2021
04/2021
06/2021
08/2021
10/2021
12/2021
02/2022
04/2022
06/2022
08/2022
10/2022
12/2022
02/2023
04/2023
06/2023
08/2023
10/2023
12/2023


Koodjeepindarranna Water Level
Koodjeepindarranna TDS
Water Surface Elevation (mRL)
TDS (mg/L)
403
402.9
402.8
402.7
402.6
402.5
402.4
402.3
900
800
700
600
500
400
300
200
100
0
09/2018
11/2018
01/2019
03/2019
05/2019
07/2019
09/2019
11/2019
12/2019
02/2020
04/2020
06/2020
08/2020
10/2020
12/2020
02/2021
04/2021
06/2021
08/2021
10/2021
12/2021
02/2022
04/2022
06/2022
08/2022
10/2022
12/2022
02/2023
04/2023
06/2023
08/2023
10/2023
12/2023


Gnalka Gnoona Water Level
Gnalka Gnoona TDS
Water Surface Elevation (mRL)
TDS (mg/L)
402.6
402.55
402.5
402.45
402.4
402.35
402.3
402.25
402.2
402.15
402.1
600
500
400
300
200
100
0
09/2018
11/2018
01/2019
03/2019
05/2019
07/2019
09/2019
11/2019
12/2019
02/2020
04/2020
06/2020
08/2020
10/2020
12/2020
02/2021
04/2021
06/2021
08/2021
10/2021
12/2021
02/2022
04/2022
06/2022
08/2022
10/2022
12/2022
02/2023
04/2023
06/2023
08/2023
10/2023
12/2023


SWML05
Rainfall
Flow Rate m3/s
Rainfall (mm)
250
200
150
100
50
0
80
70
60
50
40
30
20
10
0
09/2018
11/2018
01/2019
03/2019
05/2019
07/2019
09/2019
11/2019
12/2019
02/2020
04/2020
06/2020
08/2020
10/2020
12/2020
02/2021
04/2021
06/2021
08/2021
10/2021
12/2021
02/2022
04/2022
06/2022
08/2022
10/2022
12/2022
02/2023
04/2023
06/2023
08/2023
10/2023
12/2023

APPENDIX C
PRELIMINARY HYDROGEOLOGICAL INVESTIGATIONS

Table C1 Historic HPPL Monitoring Bore Details

Hole ID	Easting MGA_50	Northing MGA_50	Top of Casing (mRL)	Drilling Method	Drill Depth (mbgl)	Completed	SWL (mbTOC)	SWL (mRL)	Date of SWL
MDDPZ0072	666449.243	7548448.794	413.255	RC/PQ3	84.1	9/08/2014	11.18	402.125	5/05/2020
MDPZ0005	655757.993	7552847.236	413.056	OH	30	27/04/1974	11.97	401.086	27/04/1974
MDPZ0100	656477.018	7552864.885	411.579	RC	40	22/04/1994		No measurement	
MDPZ0181	655614.228	7552863.828	407.925	RC	34	29/08/2008	0	407.925	29/08/2008
MDPZ0406	656647.706	7553970.548	415.533	RC	64	19/10/2008	14.68	400.853	19/10/2008
MDPZ0407	656707.116	7554036.851	416.495	RC	64	19/10/2008	15.6	400.895	19/10/2008
MDPZ0494	655469.251	7553694.192	412.028	RC	58	16/11/2008	11.95	400.078	16/11/2008
MDPZ0540	656946.612	7553007.014	411.545	RC	70	25/11/2008	4.19	401.276	5/05/2020
MDPZ0551	656669.264	7554009.107	416.699	RC	58	28/11/2008	13.69	403.009	28/11/2008
MDPZ0572	655704.046	7552309.09	405.716	RC	70	2/12/2008	4.56	401.156	2/12/2008
MDPZ0573	655603.227	7552147.34	405.267	RC	70	3/12/2008	5.13	400.687	5/5/2020
MDPZ0574	655629.678	7552222.312	405.338	RC	52	3/12/2008	5.13	400.688	6/05/2020
MDPZ0626	654364.703	7553169.711	407.987	RC	84	15/11/2010	6.37	401.617	15/11/2010
MDPZ0641	649874.989	7548969.278	403.389	RC	144	22/11/2010	3.26	400.129	22/11/2010
MDPZ0658	649607.322	7550655.6	404.357	RC	102	29/11/2010	4.24	400.117	29/11/2010
MDPZ0667	648195.824	7550747.817	403.19	RC	108	3/12/2010	4.03	399.16	3/12/2010
MDPZ0675	647886.598	7552369.517	404.41	RC	96	6/12/2010	4.53	399.88	6/12/2010
MDPZ0704	659649.104	7549220.245	405.114	RC	88	2/04/2012	4.15	400.964	5/05/2020
MDPZ0708	657508.968	7550353.514	404.465	RC	94	4/04/2012	1.76	402.705	4/04/2012
MDPZ0745	667937.476	7549140.898	420.336	RC	82	16/04/2012	17.12	403.216	16/04/2012
MDPZ0757	669994.242	7547876.304	418.21	RC	76	19/04/2012	15.24	403.22	5/05/2020
MDPZ0817	658256.116	7552782.835	415.941	RC	64	8/05/2012	13.34	402.601	8/05/2012
MDPZ0818	663225.87	7550822.088	418.975	RC	64	8/05/2012	17.37	401.905	5/05/2020
MDPZ0908	654700.146	7553646.83	409.516	RC	40	18/05/2012	7.44	402.076	18/05/2012
MDPZ1088	654386.582	7552510.577	405.609	RC	64	10/06/2012	3.39	402.219	10/06/2012
MDPZ1089	654704.604	7552266.71	404.922	RC	64	10/06/2012	2.68	402.242	10/06/2012
MDPZ1090	655153.851	7552216.039	405.345	RC	52	12/06/2012	3.1	402.245	12/06/2012
MDPZ1091	655856.855	7551830.038	406.093	RC	70	13/06/2012	5.35	401.143	5/05/2020
MDPZ1285	656319.033	7555949.279	426.056	RC	28	3/08/2012	12.85	413.206	3/08/2012

Hole ID	Easting MGA_50	Northing MGA_50	Top of Casing (mRL)	Drilling Method	Drill Depth (mbgl)	Completed	SWL (mbTOC)	SWL (mRL)	Date of SWL
MDPZ1286	656287.41	7556004.621	426.458	RC	28	3/08/2012	14.09	412.368	3/08/2012
MDPZ1287	656337.965	7556002.751	426.375	RC	28	3/08/2012	14.02	412.355	3/08/2012
MDPZ1296	659628.527	7552958.688	421.682	RC	34	5/08/2012	19.06	402.622	5/08/2012
MDPZ2474	654529.796	7552378.875	405.398	AR	82	26/09/2012	4.1	401.298	26/09/2012
MDPZ2475	655271.209	7552357.636	405.258	AR	63	7/10/2012	4.5	400.758	7/10/2012
MDPZ2476	656846	7552502	408	AR	67	15/10/2012	8.96	399.04	15/10/2012
MDPZ2477_D	656248.351	7552011.055	407.24	AR	78	26/11/2012	5.94	401.3	26/11/2012
MDPZ2477_S	656236.049	7552014.905	407.489	AR	46	18/10/2012	6	401.489	18/10/2012
MDPZ3044	657699.617	7551643.339	408.5	RC	40	21/05/2013	6.76	401.74	21/05/2013
MDPZ3045	656893.804	7550494.264	403.895	RC	46	23/05/2013	2.5	401.395	23/05/2013
MDPZ3050	658760.781	7549676.158	404.826	RC	40	25/05/2013	3.19	401.636	25/05/2013
MDPZ3051	660131.99	7551279.865	415.385	RC	40	26/05/2013	14.58	400.975	5/05/2020
MDPZ4981	605257.718	7565393.806	390.27	RC	124	26/07/2016	No measurement		
MDPZ5003	627263.804	7555492.056	401.739	RC	148	28/07/2016	No measurement		
MDPZ5009	604455.179	7574997.249	374.523	RC	70	27/09/2017	No measurement		
MDPZ5015	607254.542	7563792.997	387.612	RC	130	3/10/2017	No measurement		
MDPZ5018	606444.842	7560997.953	393.154	RC	124	5/10/2017	No measurement		
MDPZ5032	612850	7557400	400	RC	100	10/10/2017	No measurement		
MDPZ5037	656006.241	7543006.813	405.039	RC	76	29/10/2017	No measurement		
MDPZ5040	659204.593	7540195.073	405.216	RC	76	29/10/2017	No measurement		
MDPZ5082	630850	7556600	-	RC	76	26/07/2018	No measurement		
MDPZ5110	627250	7559400	400	RC	82	14/08/2018	No measurement		

Table C2 Historic HPPL Production Bore Details

Hole ID	Easting MGA_50	Northing MGA_50	Top of Casing (mRL)	Stick-up (m)	Drilling Method	Drill Depth (mbgl)	Drill Diam (mm)	Cased Depth (mbgl)	Casing	Casing ND (mm)	Screened Depth (m)	Screened Unit(s)	Started	Completed	SWL (mTOC)	SWL (mRL)	Date of SWL
MDPB001 (Murray's Bore)	655644.72	7552208.65	406.24	-	RC	58	-	55	PVC	155	7-55	Mineralised Detritals / Nammuldi	3/12/2008	3/12/2008	5.5	401.51	05/05/2020
MDPB002[1] (East Wooley)	656665.59	7554014.76	416.03	-	RC	52	-	32	PVC	150	16-32	Mineralised Detritals / Nammuldi	28/11/2008	28/11/2008	-	-	-
MDPB003[1]	656656.19	7554047.30	416.06	-	RC	38	-	-	-	-	-	-	17/07/2012	18/07/2012	-	-	-
MDPB004[1]	673337.81	7548056.64	421.59	0.30	DTH	54.5	305.4	54.5	CL12PVC	200	18-54.5	Marra Mamba / Jeerinah	31/08/2012	9/09/2012	17.89	403.70	10/09/2012
MDPB005	663702.59	7551461.71	422.97	0.30	DTH	63	304.8	62	CL12PVC	200	19-62	Marra Mamba / Jeerinah	11/09/2012	17/09/2012	21.47	401.93	05/05/2020
MDPB006[1]	659725.13	7553112.58	421.79	0.30	DTH	60	311.15	60	CL12PVC	200	18-60	Marra Mamba / Jeerinah	17/09/2012	23/09/2012	19.08	402.71	23/09/2012
MDPB007	655585.70	7552191.85	405.18	0.32	DTH	69	-	65	Steel	254	5-65	Detritals / Marra Mamba	22/10/2012	1/11/2012	4.78	400.72	05/05/2020
MDPB008	654517.54	7552374.35	404.62	0.30	MR	82	381	77.7	Steel	254	5.7-77.7	Detritals / Marra Mamba/Jeerinah	24/10/2012	14/11/2012	4.4	400.42	05/05/2020
MDPB009	656853.23	7552498.98	410.24	0.30	DTH	64	381	59.5	Steel	254	4.5-59.5	Detritals / Marra Mamba	8/11/2012	21/11/2012	9.92	400.61	05/05/2020
MDPB0010[2]	656230.82	7551971.82	407.10	0.26	MR	64	381	28	Steel	254	0.5-26.9	Detritals / Marra Mamba	20/11/2012	9/12/2012	-	-	-

*Limited data available for MDPB003
[1]Bore was in use during time of May 2020 water level readings
[2] May 2020 water level reading assumed to be erroneous

Table C3 Details of Historic HPPL Test Pumping

Bore	SWL (mbRP)	Step Test			Constant Rate Test							
		Test Date	Step Duration (mins)	Step Discharge Rates (L/s)	Test Date	Duration (hrs)	Rate (L/s)	Max Drawdown (m)	EC Range (µS/cm)	Monitoring Bore	Distance from PB (m)	Max Drawdown (m)
MDPB001	5.21	n/a	n/a	n/a	9/12/08	26	9.1	0.11	-	MD0574	28	0.07
										MD0573	79	0.1
										MD0572	120	0.045
MDPB002	15.32	n/a	n/a	n/a	11/12/08	24	10.4	2.01	-	MD0551	7	1.00
										MD0407	50	0.68
										MD0406	45	0.565
MDPB004	18.05	6/10/12	30	5, 8, 10, 14, 18	7/10/12	24	25	0.67	-	n/a	-	-
MDPB005	20.62	30/9/12	60	10, 15, 17, 23	1/10/12	24	19	13.74	-	MD0790	~200	0.23
MDPB006	19.51	3/10/12	60	10, 15, 20, 23	4/10/19	24	23	1.96	-	MD1297	26	0.47

mbRP = metres below reference point (i.e. top of installed dip tube)

BORE LOG

Production Bore **MDPB0004**

Project *Mulga Downs* Client *HPPL* Project Number *83500226*

Location *Murrays Hills* Easting *673342* Northing *7548058* Surface Elev. *419.06 m*

Azimuth *0* Inclination *90* Hole Depth *60.0 m* Hole Diameter(mm) *154/254/305.8*

Drill Co./Rig *Mathews Drilling* Drilling Method *Air (Conventional)*

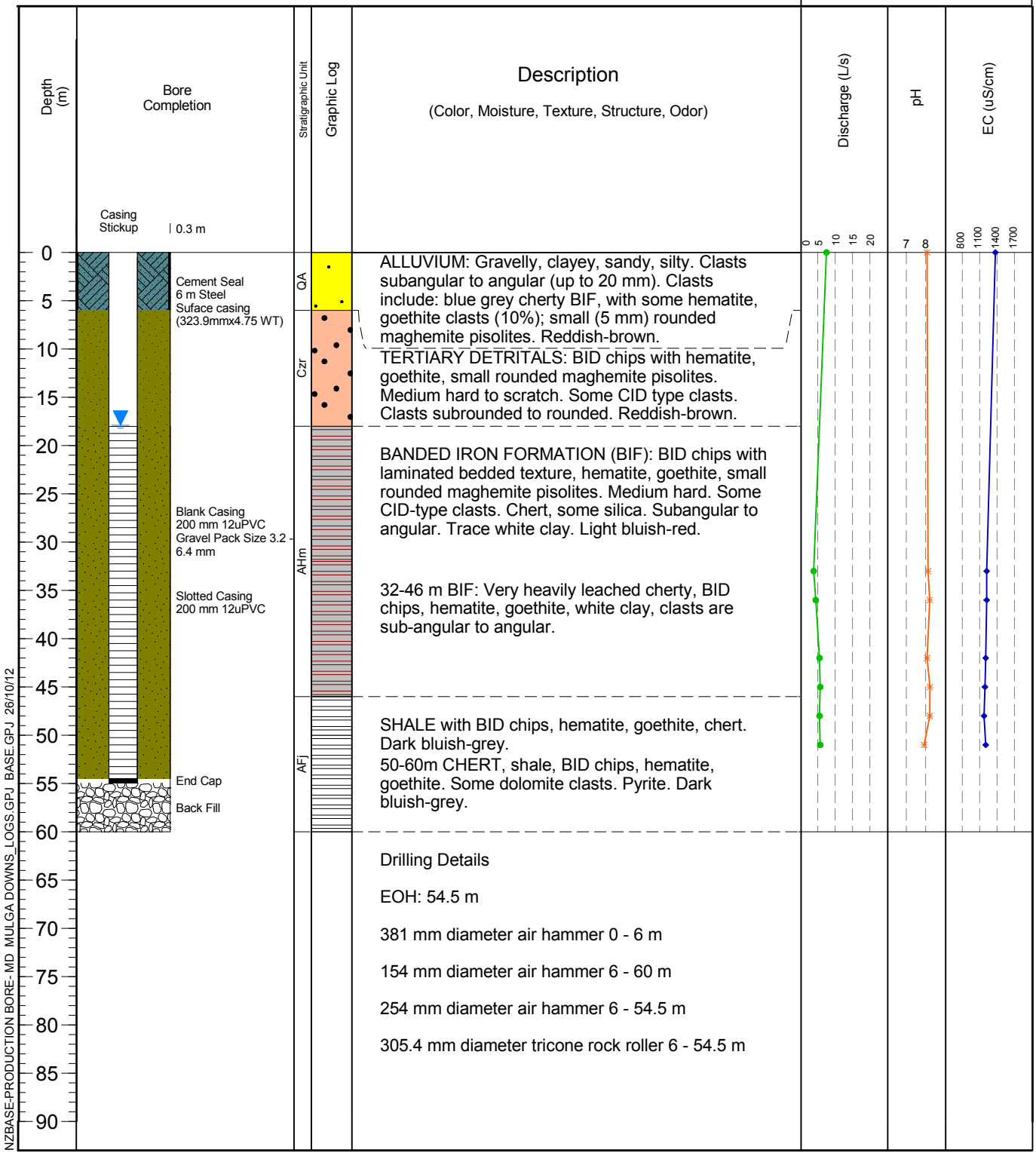
Start Date *31/08/2012* Completion Date *9/09/2012* Log By *FS* Checked By *RK*

COMMENTS

First water hit at 27 mbgl
S.W.L =17.89 m btc (10/09/2012)

EOH is 60 m with pilot hole
EOH is 54.5 with reaming out

Stratigraphic Units:
QA: Alluvium
Czr: Tertiary Detritals
AHm: Marra Mamba Formation
AFj: Jeerinah Formation



BORE LOG

Production Bore **MDPB0005**

Project *Mulga Downs* Client *HPPL* Project Number *83500226*

Location *Murrays Hills* Easting *663704* Northing *7551460* Surface Elev. *423.00 m*

Azimuth *0* Inclination *90* Hole Depth *63.0 m* Hole Diameter(mm) *154/254/304.8*

Drill Co./Rig *Mathews Drilling* Drilling Method *Air (Conventional)*

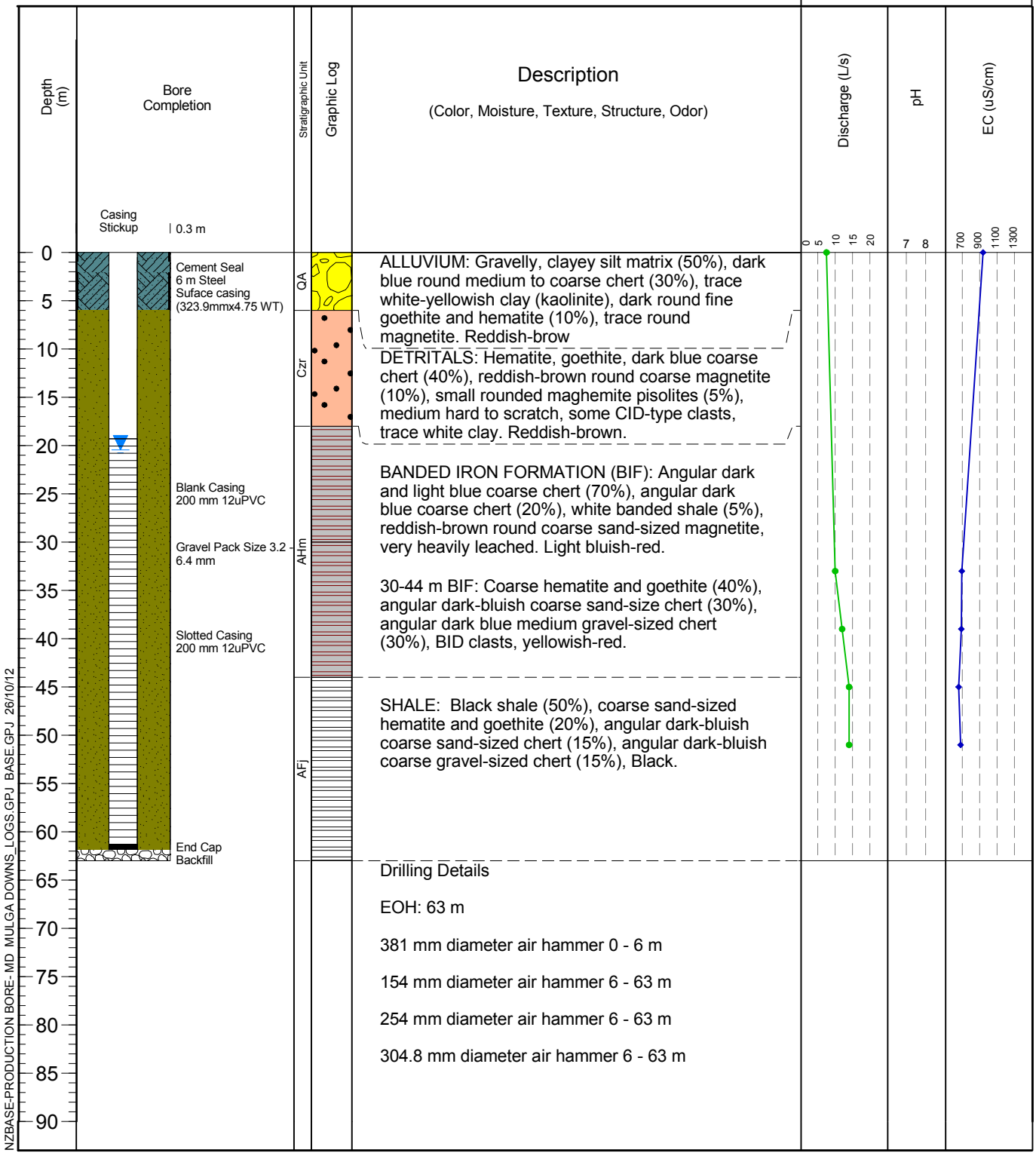
Start Date *11/09/2012* Completion Date *17/09/2012* Log By *QG* Checked By *RK*

COMMENTS

First water hit at 27 mbgl
S.W.L =20.97 m btc (16/09/2012)

Stratigraphic Units:
QA: Alluvium
Czr: Tertiary Detritals
AHm: Marra Mamba Formation
AFj: Jeerinah Formation

pH not recorded due to meter malfunction



NZBASE-PRODUCTION BORE- MD MULGA DOWNS_LOGS.GPJ BASE.GPJ 26/10/12

BORE LOG

Production Bore **MDPB0006**

Project *Mulga Downs* Client *HPPL* Project Number *83500226*

Location *Murrays Hills* Easting *659728* Northing *7553110* Surface Elev. *423.00 m*

Azimuth *0* Inclination *90* Hole Depth *60.0 m* Hole Diameter(mm) *154/203.2/311.15*

Drill Co./Rig *Mathews Drilling* Drilling Method *Air (Conventional)*

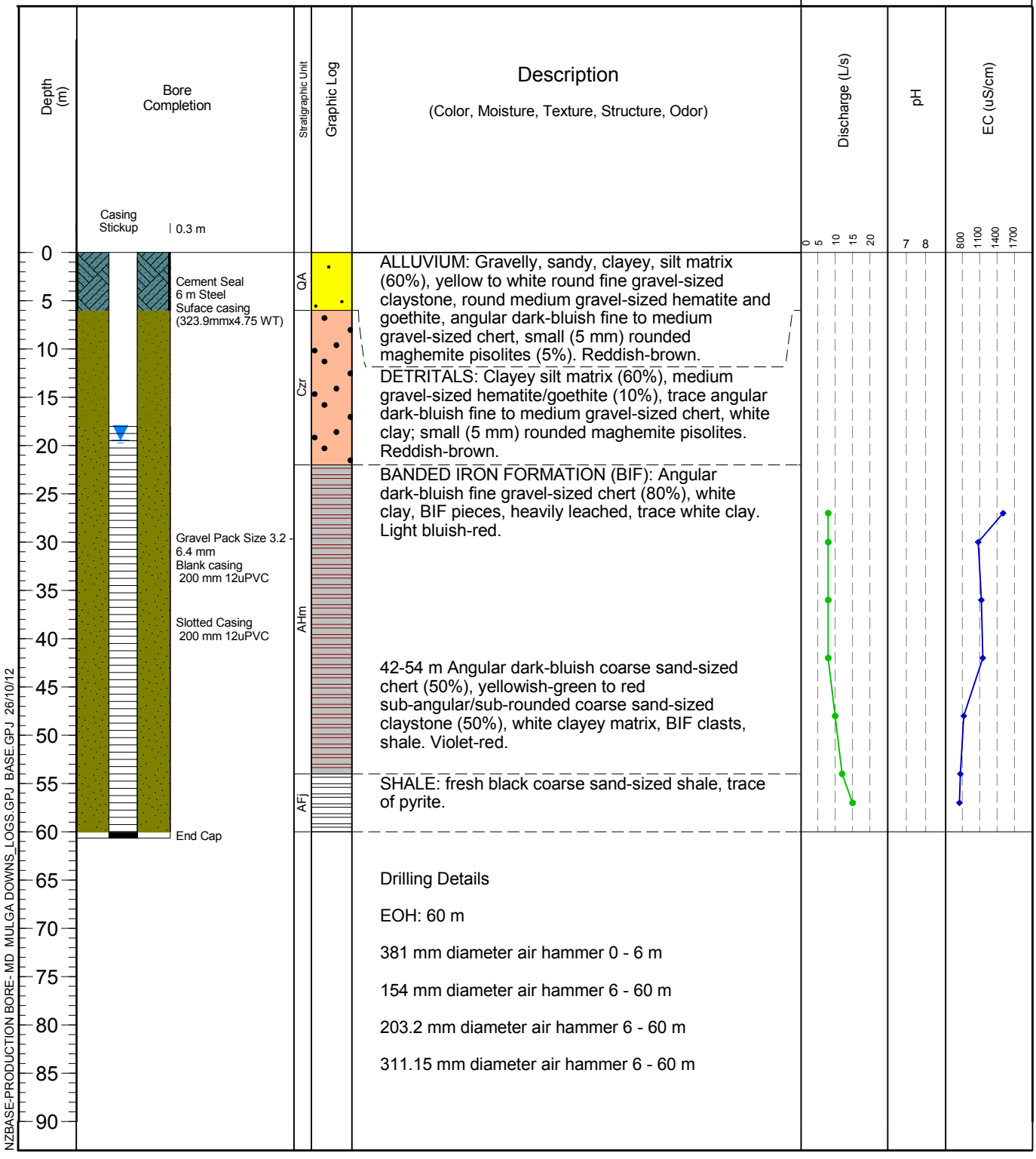
Start Date *17/09/2012* Completion Date *23/09/2012* Log By *QG* Checked By *RK*

COMMENTS

First water hit at 24 mbgl
S.W.L =19.08 m btc (23/09/2012)

Stratigraphic Units:
QA: Alluvium
Czr: Tertiary Detritals
AHm: Marra Mamba Formation
AFj: Jeerinah Formation

pH not recorded due to meter malfunction



NZBASE-PRODUCTION BORE- MD MULGA DOWNS_LOGS.GPJ BASE.GPJ 26/10/12

MDPB0007	
Details	
Location	Mulga Downs
Tenement	M47/206
Line No.	MD_8200
Easting (MGA94)	655588
Northing (MGA94)	7552193
Collar RL (m RL)	405.00
Date Drilling Commenced	22-Oct-12
Date Construction Completed	1-Nov-12
Logged By	FS
Drilling Rig	Mathews Drilling
Drilling Medium	Conventional Air Hammer

Airlift Yield Data During Drilling (178 mm)

Depth	V-notch	Q	EC	pH	Temp
(m bgl)	(mm)	(L/s)	(µs/cm)		(°C)
9	NA	~8	1320	8.8	30.1
15	NA	~8	1280	8.27	30.3
21	NA	~10	1000	7.95	30.3
27	NA	~15	970	7.67	30.1
33	NA	~15	970	7.4	30
39	NA	~15-20	980	7.1	30
45	NA	~15-20	1050	7.57	29.9
51	NA	~20	1490	7.27	30
57	NA	~20-22	1150	6.93	30.3
63	NA	~20-22	2080	8.01	30.1
69	NA	~20-22	2140	7.92	29.4

Airlift Yield Data During Drilling (381mm)

Depth	V-notch	Q	EC	pH	Temp
(m bgl)	(mm)	(L/s)	(µs/cm)		(°C)
10	NA	~10 (est)	990	8.01	29
16	NA	~10-12 (est)	980	7.78	28.6
22	NA	~12-15 (est)	1000	7.61	28.4
28	NA	~15 (est)	990	7.61	28.4
34	NA	~20-22 (est)	1040	7.35	30.5
40	NA	~22-25 (est)	1370	7.35	31
46	NA	~25 (est)	1190	7.36	31.1
52	NA	~25 (est)	1380	7.3	30.1
58	NA	~25-30 (est)	1930	7.46	30
64	NA	~35-40 (est)	1650	7.62	30.8
67	NA	~35-40 (est)	1740	7.52	30.7

Airlift Yield Data During Airlift Development

Depth	V-notch	Q	EC	pH	Temp
(m bgl)	(mm)	(L/s)	(µs/cm)		(°C)
10	NA	~10-15 (est)	1319	7.68	29.9
16	NA	~15-20 (est)	1381	7.5	30.3
22	NA	~20-25 (est)	1462	7.98	30.6
28	NA	~25-30 (est)	1564	7.47	30.4
34	NA	>30 (est)	1728	7.52	29.2
40	NA	>30 (est)	1833	7.42	29.6
46	NA	>30 (est)	1971	7.6	28.8
52	NA	>30 (est)	2030	7.37	30
58	NA	>30 (est)	2140	7.52	30.5
64	>218	>30 (Vnotch)	2190	7.51	30.5

Water Level Data

SWL (m btc)	Date
3.57	4-Dec-12

Drilling Details			(m bgl)	
Method		Diam (mm)	From	To
AH	Air Hammer/Casing	406.0	0	6
AH	Air Hammer/Casing	178.0	6	69

Construction Details	(m bgl)	
	From	To
Collar	0.0	6.0
406 mm OD x 4.75 mm WT Steel		
Blank Casing	+0.3	5
254 mm steel casing		
Slotted Casing	5.0	65.0
254 mm steel casing		
Gravel Pack	1.5	65
Size 3.2 - 6.4 mm		
Cement	0	1.5
Fallback	65	69

Casing Details	
Casing Stickup (m)	0.32 m agl
Collar Stickup (m)	0.18 m agl
Casing Material	Steel
Casing Diam (mm ID)	254
Screen Diam (mm ID)	254
Screen Aperture (mm)	1
Slot Length (mm)	300

Comments

First water is at 5 mbgl

Depth (m)	Lithological Description
0 - 6	ALLUVIUM: CLAY-SILT matrix, sub-angular to angular blue chert; hematite, goethite; some silica, rounded maghemite pisolites (~5%). Reddish-brown.
6 - 10	ALLUVIUM: CALCRETE, rounded calcrete pieces (up to 1 cm dia), some silica, blue chert, trace clay, slight trace silt. Light reddish-pink.
10 - 14	TERTIARY DETRITALS: Goethite, chert, red clay; some calcrete, trace silt. Reddish-brown.
14 - 36	TERTIARY DETRITALS: Goethite, hematite clasts, vuggy (goethite??) clasts, rounded maghemite pisolites (10 - 20%), some blue chert. Reddish-brown.
36 - 42	BANDED IRON FORMATION (BIF): BIF chips (1 - 2 cm dia), goethite, some hematite, maghemite/hematite pisolites; increasing chert; trace yellowish red shale with white clay. Red yellowish-blue.
42 - 46	BIF: As above, with higher chert/silica content, more reddish in color, smaller clast size (<0.5 cm dia).
46 - 60	BIF: CHERT (>50% silica) with laminated bedded texture, some goethite, white to yellowish clay and shale. Yellowish grey.
60 -66	SHALE: CHERT with black shale, some yellow and red shale, trace white clay. Black.
66 -69	SHALE: Black shale with Pyrite. Black.
	Total Depth = 69 m

MDPB0008					
Details					
Location		Mulga Downs			
Tenement		M47/0206			
Line No.		MD_7200			
Easting (MGA94)		654518			
Northing (MGA94)		7552369			
Collar RL (m RL)		403.00			
Date Drilling Commenced		24-Oct-12			
Date Construction Completed		14-Nov-12			
Logged By		QG			
Drilling Rig		MATHEWS DRILLING			
Drilling Medium		Mud Rotary			
Airlift Yield Data During Airlifting Development					
Depth	V-Notch	Q	EC	pH	Temp
(m bgl)	(mm)	(L/s)	(µs/cm)		(°C)
15	NA	~20 (est)	1550	7.53	30.8
24	NA	~20-22 (est)	1710	7.54	30.8
33	NA	~20-22 (est)	1830	7.57	30.9
42	NA	~25-30 (est)	1920	7.6	30.9
51	NA	~25-30 (est)	2020	7.64	31
60	NA	~30-32 (est)	2090	7.54	31
69	NA	~30-32 (est)	2120	7.47	31.1
76	NA	~25-30 (est)	2200	7.53	31.3
78	NA	~25-30 (est)	2400	7.55	30.7
Water Level Data					
SWL (m bgl)			Date		
3.28			4-Dec-12		
Drilling Details			(m bgl)		
Method			Diam	From	To
DR	Air Hammer/Casing		457.0	0	6
DR	Mud Drilling		381.0	0	82
Construction Details			(m bgl)		
			From	To	
Pre Collar 406 mm OD x 6.4 mm WT Steel			0	6	
Blank Casing 254 mm OD x 9.3 mm WT Steel			+0.3	5.7	
Slotted Casing 254 mm OD x 9.3 mm WT Steel			5.7	77.7	
Gravel Pack Size 3.2 - 6.4 mm			2	82	
Fallback			NA	NA	
Casing Details					
Casing Stickup (m)		0.3 m agl			
Collar Stickup (m)		0.17 m agl			
Casing Material		Steel			
Casing Diam (mm ID)		254			
Screen Diam (mm ID)		254			
Screen Aperture (mm)		1			
Slot Length (mm)		300			
Comments					
None					

Depth (m)	Lithological Description
0 - 2	ALLUVIUM: Clayey SILT matrix (60%), rounded hematite and goethite clasts (2 - 5 mm dia); angular, dark blue fine to coarse gravel sized chert, trace rounded maghemite pisolites. Red-brown.
2 - 4	ALLUVIUM/CALCRETE: Rounded calcrete pieces, some silica, angular blue chert, clay, silt. Light reddish-pink.
4 - 8	ALLUVIUM/CALCRETE: Sub-rounded calcrete pieces up to 30 mm dia, silica, angular blue chert clasts, clay, silt. Light reddish-pink.
8 - 14	ALLUVIUM: Sandy SILT, subangular to angular dark bluish chert up to 2 cm dia; magnetite, hematite; trace white clay. Reddish-brown
14 - 18	TERTIARY DETRITALS: Sandy SILT. Vuggy CID-type clasts. Layered BID chips, angular dark-bluish fine gravel to cobble sized CHERT (up to 10 cm). 10% rounded pisolites. Reddish-brown
18 - 22	BANDED IRON FORMATION (BIF): BID chips, layered, vuggy CID-type clasts. Dark-bluish chert (10%), rounded maghemite pisolites. Reddish-brown.
22 - 28	BIF: BID chips with white, yellow clay, some CID-type clasts. Shale, hematite, goethite. Violet-purple
28 - 42	BIF: BID chips with yellowish clay and shale; goethite, hematite, increasing chert content; trace white clay. Yellowish brown.
42 - 62	BIF: BID chips with trace white clay, shale, chert and some silica. Violet – purple.
62 - 72	BIF: Violet shale, black shale, yellowish clay, trace white clay. shale has magnetism. Violet- purple-black yellow.
72 - 82	SHALE: Violet shale, black shale, some BIF, yellowish clay, trace white clay. shale has magnetism. Some pyrite. (Jeerinah Formation??)
	TD = 82 m
	Field samples appeared to indicate Jeerinah contact at 72 m. Gamma log in adjacent MDPZ0952 was inconclusive. Jeerinah contact in the general area and a few hunderd meters on either side of drill location encountered at approx 70 m. Current interpretation is based on input from HPPL senior geologists at the site. Samples from mud drilling compounded sample identification and interpretation.

MDPB0009	
Details	
Location	Mulga Downs
Tenement	M47/0206
Line No.	MD_9000
Easting (MGA94)	656853
Northing (MGA94)	7552501
Collar RL (m RL)	412.00
Date Drilling Commenced	8-Nov-12
Date Construction Completed	21-Nov-12
Logged By	QG
Drilling Rig	MATHEWS DRILLING
Drilling Medium	Mud

Airlift Yield Data During Drilling (178mm)

Depth	V-Notch	Q	EC	pH	Temp
(m bgl)	(mm)	(L/s)	(µs/cm)		(°C)
31	NA	~10-15 (est.)	1054	7.66	28.6
37	NA	~15 (est.)	1062	7.6	28.2
43	NA	~15-20 (est.)	1068	7.66	29.5
49	NA	~15-20 (est.)	1256	7.7	29.5
55	NA	~15-20 (est.)	1321	7.77	28.9
61	NA	~20 (est.)	1492	7.78	29.2
64	NA	~20 (est.)	1667	7.79	29.3

Airlift Yield Data During Reaming out (381mm)

Depth	V-Notch	Q	EC	pH	Temp
(m bgl)	(mm)	(L/s)	(µs/cm)		(°C)
12	NA	~10 (est)	1370	8.13	32.1
18	NA	~15 (est)	920	8.17	32.1
26	NA	~15-20 (est)	920	7.88	29.5
32	NA	~20-22 (est)	930	7.74	29.6
38	NA	~20-22 (est)	1060	7.7	30.1
44	NA	~22-25 (est)	1100	7.67	30.4
50	NA	~30 (est)	1170	7.78	29.8
56	NA	~30 (est)	1310	7.75	30.4
62	NA	~35-40 (est)	1210	7.8	30.7

Airlift Yield Data During Airlifting Development

Depth	V-Notch	Q	EC	pH	Temp
(m bgl)	(mm)	(L/s)	(µs/cm)		(°C)
55		>25	1170	7.54	29.9

Water Level Data

SWL (m bgl)	Date
8.54	4-Dec-12

Drilling Details			(m bgl)	
Method		Diam	From	To
DR	Air Hammer/Casing	457.0	0	6
DR	Air Hammer/Casing	178.0	0	64
DR	Air Hammer/Casing	381.0	0	64

Construction Details	(m bgl)	
	From	To
Pre Collar 406 mm OD x 6.4 mm WT Steel	0	6
Blank Casing 254 mm OD x 9.3 mm WT Steel	+0.3	4.5
Slotted Casing 254 mm OD x 9.3 mm WT Steel	4.5	59.5
Gravel Pack Size 3.2 - 6.4 mm	1.1	59.5
Cement	0	1.1
Fallback	59.5	62

Casing Details

Casing Stickup (m)	0.3 m agl
Collar Stickup (m)	0.20 m agl
Casing Diam (mm ID)	254
Screen Diam (mm ID)	254
Screen Aperture (mm)	1
Slot Length (mm)	300

Comments

First water is at 12 mbgl.

Depth (m)	Lithological Description
0 - 4	ALLUVIUM: SILT matrix scree deposits, angular blue chert clasts (<1 cm dia) (~10%), maghemite pisolites (1 - 3 mm dia) (<10%). Reddish-brown.
4 - 14	TERTIARY DETRITALS: Sub-rounded hematite, goethite clasts (< 1 cm dia); angular blue chert (up to 1 cm dia); some pisolites; trace yellowish-brown clay and white clay. Yellowish to reddish-brown.
14 - 20	TERTIARY DETRITALS: As above with higher pisolites content (10 - 20%); chert clasts up to 2 cm dia; trace white to yellowish clay. Reddish-brown.
20 - 38	BANDED IRON FORMATION (BIF): Sub-angular clasts of predominantly hematite and some goethite, well rounded magnetic pisolites, trace yellowish-white clay. Reddish brown.
38 - 58	BIF: Increasing chert content; angular greyish-green chert clasts, greenish-gray; trace white to yellowish clay
58 - 60	BIF: Greyish-blue chert, reddish clay.
62 - 64	SHALE: Black shale (Jeerinah Formation shale)
	TOTAL DEPTH: 64 m.

MDPB0010

Details

Location	Mulga Downs
Tenement	M47/206
Line No.	MD_8800
Easting (MGA94)	656231
Northing (MGA94)	7551973
Collar RL (m RL)	412.00
Date Drilling Commenced	20-Nov-12
Date Construction Completed	9-Dec-12
Logged By	FS
Drilling Rig	Mathews Drilling
Drilling Medium	Mud Rotary

Airlift Yield Data During Drilling (153 mm)

Depth	V-notch	Q	EC	pH	Temp
(m bgl)	(mm)	(L/s)	(µs/cm)		(°C)
19	NA	~2-3 (est)	1080	8.14	30.5
25	NA	~2-3 (est)	1100	8.17	29.4
31	NA	~5-8 (est)	1090	7.86	30.3
37	NA	~8-10 (est)	1130	8.05	30.4
43	NA	~10 (est)	110	8.07	30
49	NA	~10-12 (est)	1470	7.89	30.1
55	NA	~15-20 (est)	1500	7.63	30
61	NA	~15-20 (est)	1610	7.85	30.5
67	NA	~20-22 (est)	1620	8	29.4
73	NA	~20-22 (est)	1920	8.1	30.1

Airlift Yield Data During Drilling (381mm)

Depth	V-notch	Q	EC	pH	Temp
(m bgl)	(mm)	(L/s)	(µs/cm)		(°C)
20	NA	~8-10 (est)	1410	8.13	30.1
26	NA	~10-12 (est)	1300	8.1	30.1
32	NA	~12-15 (est)	1280	7.52	29.9
38	NA	~15 (est)	1330	7.84	30.3

Airlift Yield Data During Drilling (305mm)

Depth	V-notch	Q	EC	pH	Temp
(m bgl)	(mm)	(L/s)	(µs/cm)		(°C)

Airlift Yield Data During Airlift Development

Depth	V-notch	Q	EC	pH	Temp
(m bgl)	(mm)	(L/s)	(µs/cm)		(°C)
28		~10-12 (est)	1500	8.23	28.7

Water Level Data

SWL (m toc)	Date
5.57	11-Dec-12

Drilling Details

	Method	Diam (mm)	From (m bgl)	To (m bgl)
AH	Air Hammer/Casing	406.0	0	6
AH	Air Hammer/Casing	153.0	6	73
FRC	Flooded Reverse Circulation	381.0	6	26.0
MR	Mud Rotary	381.0	6	64.0

Construction Details

	From (m bgl)	To (m bgl)
Collar	0.0	6.0
406 mm OD x 4.75 mm WT Steel		
Blank Casing		
254 mm steel casing		
Slotted Casing	0.5	26.9
254 mm steel casing		
Gravel Pack	0.5	28
Size 3.2 - 6.4 mm		
Cement	0	0.5
Fallback	28	73

Casing Details

Casing Stickup (m)	0.26
Collar Stickup (m)	0.15
Casing Material	Steel
Casing Diam (mm ID)	254
Screen Diam (mm ID)	254
Screen Aperture (mm)	1
Slot Length (mm)	300

Comments

Crew had previously attempted drilling with air and foam but was unsuccessful. Further drilling utilizing Flooded Reverse Circulation (FRC) method also was unsuccessful. Mud Rotary (MR) drilling was utilized to advance the hole to 64 mbgl, where the rods got jammed down hole. Retrieval of the rods indicated hole was open to 26 mbgl. Steel bore casing installation without bottom end cap (and airlifting inside the casing as necessary to facilitate casing advancement) was initiated, but was suspended at 28 mbgl due to formation instability. The bore was ultimately cased to 28 mbgl with a 60cm cement plug placed at the bottom of the casing. First water was encountered at 12 mbgl.

Depth (m)	Lithological Description
0 - 4	ALLUVIUM: SILT to CLAY matrix, angular blue chert clasts up to 1 cm dia (>40%); sub-rounded to well-rounded hematite pisolites; trace white clay; trace calcrete. Reddish-brown.
4 - 10	ALLUVIUM: CALCRETE,medium sand-sized vuggy clasts, rounded hematite pisolites, coarse sand-sized to medium sand-sized CHERT. Reddish-brown.
10 - 20	TERTIARY DETRITALS: SILT to CLAY matrix, angular blue chert clasts (up to 1 cm dia); goethite, hematite; sub-rounded hematite pisolites (1 - 3 mm dia) (10 - 15%). Reddish-brown.
20 - 34	TERTIARY DETRITALS: Well-rounded hematite pisolites (>35%, highly magnetic); hematite, goethite clasts (up to 0.5 cm dia); some angular chert clasts; trace white clay. Reddish-brown.
34 - 54	TERTIARY DETRITALS: As above with vuggy clasts; some yellow silt, trace white clay. Yellowish-Red.
54 - 70	BANDED IRON FORMATION (BIF): Cherty BIF with some vuggy clasts; goethite, hematite; violet – purple shale with trace white clay. Reddish-brown. Interpretation compounded by substantial pisolites, possibly sample contamination from above.
70 -73	BIF: Shaley BIF with some vuggy clasts, violet – purple shale with trace white clay. Trace black shale and trace pyrite. Reddish-brown.
	Total Depth = 73 m
	Note: Interpretation of samples at depth compounded by the presence of magnetic pisolites throughout sample column; pisolites at depth may be a result of sample contamination from overlying horizons.

APPENDIX D
BORE COMPLETION LOGS 2018–2023

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COMPOSITE WELL LOG

Bore No: MDPB0011

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 3/05/2019
Completed: 6/05/2019
Drilled: Ausdrill NW
Logged By: LC

Method: DR
Fluid: Air
Bit Record: 0-23.5m = 406mm

Area: Mulga Downs
Elevation: 406.17 mAHD
Easting: 652201.7
Northing: 7552524.9
Projection: MGA94 Zone 50

Static Water Level: 6.19 mbtoc **Date:** 8/09/2019

Remarks: Stick up: 0.41m

Depth (mbgl)	Strat	Graphic Log	Lithological Description	Aquifer	Field Notes	Well Completion: Diagram	Well Completion: Notes
0 – 10	Alluvial Fan		Alluvium: Some sections grey/black/white, other sections yellowy brown due to matrix. Larger sub angular clasts up to 4cm, poorly sorted.		Adjacent to MDPZ7450 Airlift: 2 L/s, EC: 697 uS/cm, pH: 7.76	0-48 = cement/bentonite grout 48-49.5m = bentonite seal 250mm CL12 PVC Blank Casing	
10 – 20	Upper Calcrete		Calcrete: Light brown, friable, unstructured fragments of calcrete with clasts of chert and minor pisolites. Clay becoming dominant at 18m.		Airlift: 2.2 L/s, EC: 804 uS/cm, pH: 8.14	49.5-58m = gravel pack (3.2-6.4mm) 250mm CL12 PVC Slotted Casing	
20 – 30	Pisolite		Pisolitic Clay: Dark red/brown, Sub rounded weakly magnetic pisolites, dominated by a clay matrix.		Airlift: 2.9 L/s, EC: 849 uS/cm, pH: 8.3 Completed Airlift: 3.8 L/s		
30 – 40							
40 – 50							

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COMPOSITE WELL LOG

Bore No: MDPB0012

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 6/05/2019
Completed: 9/05/2019
Drilled: Ausdrill NW
Logged By: TV

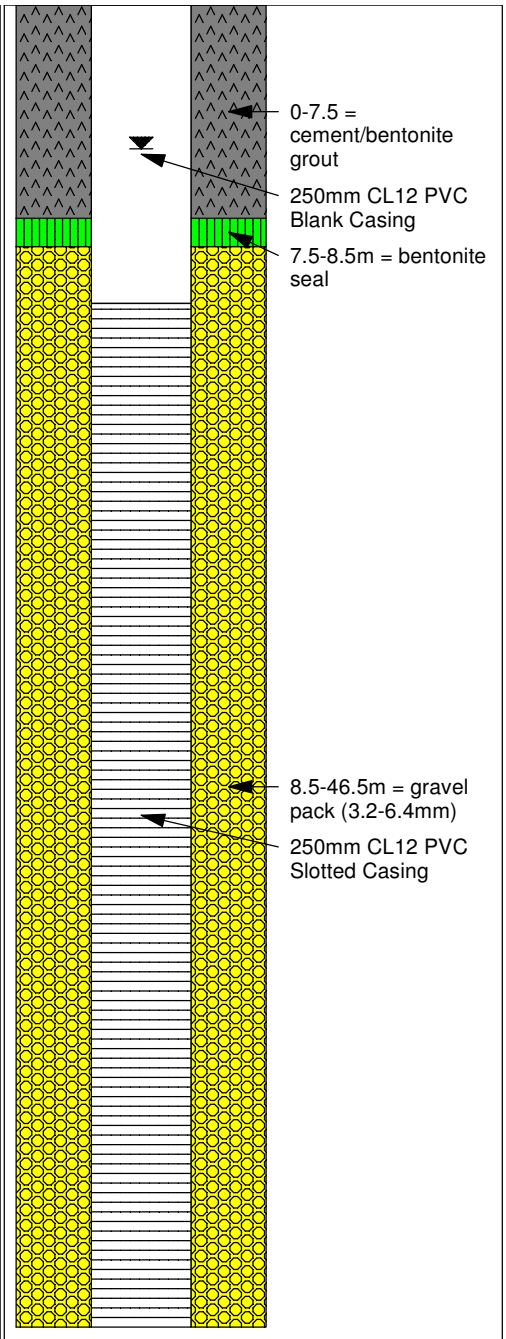
Method: DR
Fluid: Air
Bit Record: 0-46.5m = 406mm

Area: Mulga Downs
Elevation: 400.45 mAHD
Easting: 655667.3
Northing: 7551805.1
Projection: MGA94 Zone 50

Static Water Level: 5.06 mbTOC **Date:** 8/09/2019

Remarks: Stick up: 0.35m

Depth (mbgl)	Strat	Graphic Log	Lithological Description	Aquifer	Field Notes	Well Completion Diagram	Well Completion Notes
0	Alluvium		Alluvium: Red-brown, medium to fine grained sub angular clasts in a clay matrix, becoming coarse to fine grained at 2m with calcrete in clay matrix.		Adjacent to MDPZ7449		
	Upper Calcrete		Calcrete: White and light-brown, friable, vuggy, unstructured calcrete.				
10	Undiff. Tertiary		Clayey Gravel: Red-brown to dark brown/grey, sub rounded pisolites up to 1cm, angular chert fragments up to 5cm, poorly sorted in a clay matrix, magnetic, clay and chert content decreasing with depth as pisolites become dominant.		Airlift: 2.9 L/s, EC: 962 uS/cm, pH: 7.77		
20					Airlift: 1.8 L/s, EC: 1254 uS/cm, pH: 7.89		
30	CID/Pisolite		Pisolite: Dark brown/grey, sub rounded pisolites up to 1cm in a clay matrix, poorly sorted, magnetic.		Airlift: 5.6 L/s, EC: 1447 uS/cm, pH: 7.96		
40			CID/Hardcap: Dark brown/grey and yellow. Pisolites sub rounded, ore fragments angular, poorly sorted, magnetic, limonitic/goethitic alteration.		Airlift: 10.3 L/s, EC: 1408 uS/cm, pH: 7.99		
					Airlift: 15 L/s, EC: 1348 uS/cm, pH: 7.90		
50					Airlift: 10.3 L/s, EC: 1647 uS/cm, pH: 7.95		
					Completed Airlift: 15 L/s		



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COMPOSITE WELL LOG

Bore No: MDPB0013

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 12/05/2019
Completed: 17/05/2019
Drilled: Ausdrill NW
Logged By: TV

Method: 0-57 = DR. 57-112 = DTH
Fluid: Air
Bit Record: 0-57m = 406mm
57-112m = 375mm

Area: Mulga Downs
Elevation: 404.75 mAHD
Easting: 656694.1
Northing: 7548124
Projection: MGA94 Zone 50

Static Water Level: 4.88 mbtoc **Date:** 8/09/2019

Remarks: Stick up: 0.37m

Depth (mbgl)	Strat	Graphic Log	Lithological Description	Aquifer	Field Notes	Well Completion Diagram	Well Completion Notes
0	CalcAlluvium		Alluvium: Red-brown, soft, sticky, plastic clay with minor (15%) subrounded, mixed gravel clasts.		Adjacent to MDPZ7460 Very hard ground (chert) was encountered at 55 m during the drilling of MDPB0013, causing the loss / detachment of the drive shoe from the DR casing. The first attempt of this hole was therefore abandoned, and a new hole was drilled adjacent to it.	0-20m = backfill	
10			Calcrete: Brown, hard, reactive, massive, subrounded.				
20	Undiff. Tertiary		Alluvium: Multicoloured, subrounded, mixed, coarse gravels in a fine-grained silty matrix. Hard, round, magnetic pisolites increase towards base of unit.		Airlift: 1.1 L/s, EC: 2860 uS/cm, pH: 8.08		
30			Alluvium: Red-brown and dark-grey, rounded, medium- to coarse-grained, magnetic pisolites with minor (10%), subrounded, mixed, coarse gravels.		Airlift: 4.3 L/s, EC: 3540 uS/cm, pH: 7.92	250mm CL12 PVC Blank Casing	
40					Airlift: 8 L/s, EC: 2370 uS/cm, pH: 8.09	20-58 = cement/bentonite grout	
50			Laterite: Hydrated-Hardcap/Chert: Yellow/grey, subangular, weakly weathered, strongly bedded chert and red-yellow, ferruginous and manganiferous laterite (hardcap).		Airlift: 8 L/s, EC: 2740 uS/cm, pH: 7.95		
			Chert: Light-grey, hard, subangular, bedded chert and soft, sticky, green-grey clay.		Airlift: 12 L/s		
60			Chert: Brown, grey and green, very hard, subangular - angular, strongly bedded, fine-grained, glassy, well-sorted.		Airlift: 15 L/s, EC: 3800 uS/cm, pH: 7.90	58-60m = bentonite seal	
70					Airlift: 5 L/s, EC: 4460 uS/cm, pH: 8		
					Airlift: 8 L/s, EC: 4820 uS/cm, pH: 8.19		
80	Marra Mamba		Shale: Dark-grey to black, finely laminated, well-sorted, subangular to subrounded, fine-grained carbonaceous shale. Minor, thin but hard bands of well-bedded, pink and brown chert esp. 84-92m.		Airlift: 10 L/s, EC: 4770 uS/cm, pH: 8.26		
					Airlift: 10 L/s, EC: 4860 uS/cm, pH: 8.34	60-112m = gravel pack (3.2-6.4mm)	
90					Airlift: 15 L/s, EC: 5000 uS/cm, pH: 8.31	250mm CL12 PVC Slotted Casing	
					Airlift: 15 L/s, EC: 4730 uS/cm, pH: 8.21		
100					Airlift: 19.3 L/s, EC: 4860 uS/cm, pH: 8.32		
					Airlift: 19.3 L/s, EC: 4860 uS/cm, pH: 8.32		
110					Airlift: 20.7 L/s, EC: 4820 uS/cm, pH: 8.26		
					Completed Airlift: 10.3 L/s		
120							

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COMPOSITE WELL LOG

Bore No: MDPB0014

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 18/05/2019
Completed: 20/05/2019
Drilled: Ausdrill NW
Logged By: ATS

Method: 0-35m = DR
Fluid: Air
Bit Record: 0-35m = 406mm

Area: Mulga Downs
Elevation: 404.93 mAHD
Easting: 651168.5
Northing: 7549452.2
Projection: MGA94 Zone 50

Static Water Level: 4.58 mbtoc **Date:** 8/09/2019

Remarks: Stick up: 0.38m

Depth (mbgl)	Strat	Graphic Log	Lithological Description	Aquifer	Field Notes	Well Completion Diagram	Well Completion Notes
0 – 10	Upper Calcrete		Calcrete: White, very hard, low yields.		Adjacent to MDPZ7457		0-1 = cement/bentonite grout 1-3m = bentonite seal 250mm CL12 PVC Blank Casing
10 – 20	Upper Calcrete		Calcrete: Light-brown, subangular, vuggy, porous. Reacts variably to acid.		Airlift: 8 L/s, EC: 5160 uS/cm, pH: 7.96		3-35m = gravel pack (3.2-6.4mm) 250mm CL12 PVC Slotted Casing
20 – 30					Airlift: 10 L/s, EC: 5270 uS/cm, pH: 8.03		
30 – 40					Airlift: 12 L/s, EC: 5550 uS/cm, pH: 8.04 Completed Airlift: 8 L/s		
40 – 50							

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COMPOSITE WELL LOG

Bore No: MDPB0015

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 5/08/2019
Completed: 9/08/2019
Drilled: Ausdrill NW
Logged By: ATS

Method: 0-52m = DR
Fluid: Air
Bit Record: 0-52m = 406mm

Area: Mulga Downs
Elevation: 403.91 mAHD
Easting: 651326.8
Northing: 7545796.9
Projection: MGA94 Zone 50

Static Water Level: 4.61 mbtoc **Date:** 03/09/2019

Remarks: Stick up: 0.24m

Depth (mbgl)	Strat	Graphic Log	Lithological Description	Aquifer	Field Notes	Well Completion: Diagram	Well Completion: Notes
0	Upper Calcrete		Calcrete: Yellow-brown to light-yellow, friable, vuggy. Reacts strongly to acid.		Adjacent to MDPZ7452		
10							
20					Airlift: 4 L/s, EC: 4790 uS/cm		0-26 = cement/bentonite grout; 250mm CL12 PVC Blank Casing
					Airlift: 8 L/s, EC: 5190 uS/cm		
30	Undiff. Tertiary		Alluvium: Red-brown, poorly-sorted, mixed clasts in a silty matrix. Gradational boundary between calcrete.		Airlift: 8 L/s, EC: 5260 uS/cm		26-30m = bentonite seal
					Airlift: 20 L/s, EC: 5550 uS/cm		
40					Airlift: 30 L/s, EC: 5380 uS/cm		30-52m = gravel pack (3.2-6.4mm); 250mm CL12 PVC Slotted Casing
					Airlift: 40 L/s, EC: 5660 uS/cm		
50	CID/Pisoli		Pisolite: Dark-grey to yellow-brown, well-rounded, hard, magnetic with mixed clasts of chert and BIF.		Airlift: 50 L/s, EC: 6420 uS/cm Completed Airlift: 30 L/s		

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COMPOSITE WELL LOG

Bore No: MDPB0016

Client: Roy Hill

Project: Mulga East PFS Investigations

Commenced: 16/08/2021
Completed: 24/08/2021
Drilled: Pentium Hydro
Logged By: A.S

Method: DR
Fluid:
Bit Record: 0-88m = 432mm

Area: Mulga East
GL Elevation: 403.84 mAHD
Easting: 657318
Northing: 7550024
Projection: MGA94_Z50

Static Water Level: 3.25 mbtoc
Date: 25/08/2021

Remarks: PVC stick up = 0.48

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Drilling Yield (L/s)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0	Alluv		Gravel: Red-brown clayey matrix, pisolites 1-2mm rounded (non-magnetic), quartz crystals, tree roots, minor dark grey vitreous goethite and shales, all chips finely ground (hard drilling)			AWT - Injecting water	0 -5m = Cement Seal	
10	Upper Calcrete		Calcrete: White calcrete (strong fizz with HCl) and brown silt/clay, minor quartz crystals and lithic chips			AWT - Injecting water	Blank PVC CL12, 250mm	
20			Gravel: Red-brown clayey, gravelly			EC: 1670 uS/cm, pH: 7.68, Temp: 30.8°C, FWS @16m, Mud-brown, viscous	5-6m = bentonite seal	
30	Undifferentiated		Clay: Red-brown clay, maghemite pisolite, gravel, minor white and yellow shales, minor vitreous goethite. Pink-white shale 28-30m.			EC: 930 uS/cm, pH: 7.48, Temp: 30.3°C, Mud-brown, viscous		
40			Gravel: Red-brown clay, white pink and yellow shales, some blue-grey chert, minor goethite			EC: 1103 uS/cm, pH: 7.61, Temp: 30.1°C, Mud-brown, viscous		
50	CID Pisolite		Pisolite: Hematite pisolite red streak magnetic, minor white and yellow shales	0 1000 2000 3000 4000 5000	0 6 12 18 24 30	EC: 1788 uS/cm, pH: 7.18, Temp: 30.0°C, Mud-brown, viscous		
	Basal Creli		Calcrete: White calcrete (strong fizz with HCl), red-brown clay, maghemite pisolites from above			EC: 1950 uS/cm, pH: 7.69, Temp: 30.4°C, Mud-brown, viscous		
60	Marra Mamba		Shale: Yellow limonitic high plasticity clay with blue-grey goethite brown streak			EC: 2600 uS/cm, pH: 7.99, Temp: 30.3°C, Mud-brown, viscous; fines settling		
			Hardcap: Blue-grey vuggy goethite brown streak with yellow limonitc coating			EC: 2470 uS/cm, pH: 7.90, Temp: 31.2°C, Mud-brown, viscous; fines settling		
70			Shale: White sticky high plasticity clay with vuggy goethite and minor red shale. 64-66m transition zone with minor calcrete (fizz with HCl). 72-24m limonitic yellow shale also.			EC: 1930 uS/cm, pH: 8.20, Temp: 31.3°C, Light brown, viscous		
80						EC: 2830 uS/cm, pH: 8.17, Temp: 30.4°C, Yellow tinge, cloudy, opaque		
						EC: 2800 uS/cm, pH: 8.12, Temp: 29.6°C, Yellow tinge, opaque, foam		
90	Jeeri		BIF: Blue-grey vitreous goethite brown streak, yellow-brown goethite interbedded with red shale, yellow limonitic coating, minor red shale, minor angular hard cloudy chert			EC: 2800 uS/cm, pH: 8.02, Temp: 30.0°C, Yellow-brown, opaque, foam		
						EC: 2830 uS/cm, pH: 7.99, Temp: 29.8°C, Light brown, opaque, foam		
100			BIF: Transition sample as above with black shale (greasy sheen on water) and gold pyrite.			EC: 2890 uS/cm, pH: 7.99, Temp: 30.2°C, Brown, opaque, foam	6-88m = gravel pack (3.2-6.4mm)	
						EC: 2960 uS/cm, pH: 8.00, Temp: 30.0°C, Orange-brown, opaque	10-88m = 250mm Slotted PVC CL12, 1mm aperture	

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COMPOSITE WELL LOG

Bore No: MDPB0017

Client: Roy Hill

Project: Mulga Downs PFS Investigations

Commenced: 25/08/2021
Completed: 29/08/2021
Drilled: Pentium Hydro
Logged By: AS

Method: DR / DTH
Fluid: Air
Bit Record: 432mm (0-88m)
368mm (88-100m)

Area: Mulga East
GL Elevation: 413.33mAHD
Easting: 666388
Northing: 7548453
Projection: MGA94_Z50

Static Water Level: 11.75 mbtoc
Date: 02/09/2021

Remarks: PVC stick up = 0.46

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Drilling Yield (L/s)	Field Notes	Well Completion: Diagram / Notes
0–30	Undifferentiated		Gravel: Gravel - sand sized clasts comprising chert, quartz and ferruginous lithics. Rounded-angular, poorly sorted in a red silty/clayey matrix. Smaller clast size from 10-16m.			0-22m AWT- Injecting	0-8.5m = cement seal; Blank PVC CL12, 250mm; 8.5-10m = bentonite seal
30–40	CID Pisolite		Pisolite: Dark grey/black, fine - coarse grained (0.1-10mm), moderately sorted, rounded, highly magnetic. Minor CID at 40m.			EC: 1626 uS/cm, Red and muddy; EC: 1067 uS/cm, Temp: 29.8°C, Red and muddy	
40–50	CID Pisolite		CID: Red-brown and black with metallic lustre, vuggy, friable, high iron content			EC: 1435 uS/cm, Temp: 29.9°C, Red and muddy	
50–70	CID Pisolite		CID: Yellow/light pink becoming dark brown/grey at 62m, fairly soft and friable with minimal iron content.	0, 1000, 2000, 3000, 4000, 5000	0, 12, 24, 36, 48, 60	EC: 2620 uS/cm, pH: 8.01, Temp: 30.5°C, Light brown and translucent; EC: 2800 uS/cm, pH: 7.93, Temp: 30.9°C, Light brown and translucent; EC: 2830 uS/cm, pH: 7.93, Temp: 30.0°C, Light brown and translucent; EC: 2770 uS/cm, pH: 7.94, Temp: 30.4°C, Light brown and translucent	10-100m = gravel pack (3.2-6.4mm); 16-100m = 250mm Slotted PVC CL12, 1mm aperture
70–80	Marra Mamba		BIF: Dark grey with a purple tinge, flaky and soft. Moderately magnetic.			EC: 2820 uS/cm, pH: 7.82, Temp: 30.2°C, Brown and purple; EC: 2810 uS/cm, pH: 7.76, Temp: 30.2°C, Purple	
80–100	Marra Mamba		Chert: Dark grey with brown staining, hard			EC: 2750 uS/cm, pH: 8.01, Temp: 30.6°C, Purple; EC: 2720 uS/cm, pH: 7.95, Temp: 30.4°C, Purple-brown; EC: 2610 uS/cm, pH: 8.17, Temp: 29.8°C, Brown and transparent; EC: 2660 uS/cm, pH: 8.06, Temp: 30.4°C, Brown and transparent	

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COMPOSITE WELL LOG

Bore No: MDPB0018

Client: Roy Hill

Project: Mulga East PFS Investigations

Commenced:	30/08/2021	**Method:**	DR / DTH	**Area:**	Mulga East
Completed:	4/09/2021	**Fluid:**	Air	**GL Elevation:**	421.09 mAHD
Drilled:	Pentium Hydro	**Bit Record:**	0-88m = 432mm	**Easting:**	669188
Logged By:	A.S		88-91m = 368mm	**Northing:**	7549120
				Projection:	MGA94_Z50
Static Water Level:	18.50 mbtoc	**Date:**	10/09/2021	**Remarks:**	PVC stick up = 0.41

Depth (mbgl)	Strat / Hydro	Graphic Log	Lithological Description	EC (µS/cm)	Drilling Yield (L/s)	Field Notes	Well Completion Diagram	Well Completion Notes
0–10	Undifferentiated		Silt/Clay: Alluvium: red brown silt-clay matrix with poorly sorted chips 2-8mm diameter, cherty hard to soft clays, subangular to subrounded.		0 12 24 36 48 60	AWT- Injecting	0-5m = cement seal	
10–20	Undifferentiated		Silt/Clay: Alluvium: As above, but light orange-brown silty clay matrix			AWT- Injecting	Blank PVC CL12, 250mm	
20–30	Undifferentiated		Clay: Red-brown, significant increase in clay making majority of sample, minor chip return, maghemite pisolite, minor white clays, blue-grey chert.			AWT- Injecting		
30–40	CID Pisolite		Pisolite: Maghemite pisolite, finely ground chips			AWT- Injecting		
40–50	CID Pisolite		Pisolite: As above			AWT- Injecting		
50–60	CID Pisolite		CID: Red brown vuggy clasts with yellow goethititic staining, minor dark grey vitreous goethite, minor white clay.			EC: 495uS/cm, pH: 8.7.76, Temp: 31.9C, brown opaque	5-91m = gravel pack (3.2-6.4mm)	
60–70	Marra Mamba		Shale: Pink and white mod plasticity, sticky clay	0 1,000 2,000 3,000 4,000 5,000		EC: 740uS/cm, pH: 7.81, Temp: 29.3C, brown, opaque, foam	13-91m = 250mm Slotted PVC CL12, 1mm aperture	
70–80	Marra Mamba		Chert: Blue-grey bedded angular hard banded chert, white clayey coating, iron enriched purple shales with dark red smear, non-magnetic nodular concretions on BIF samples from 56-58m, white and pink soft clay/shale pods 66-68m, yellow shale pods 68-70m, white and pink shales 72-76m.		0 12 24 36 48 60	EC: 1005uS/cm, pH: 7.81, Temp: 30.6C, light brown, semi transparent		
80–90	Marra Mamba		Shale: Red-purple shales, blue-grey chert, minor white clay			EC: 837uS/cm, pH: 7.56, Temp: 29.7C, light brown, semi-transparent		
90–100	Marra Mamba		Shale: Transitioning red-purple to dark grey-black shales and minor chert, minor white and red shales, and white quartz crystals 80-82m			EC: 1054uS/cm, pH: 7.64, Temp: 30.4C, light brown, semi-transparent		
	Marra Mamba		Shale: Black-grey soft-mod shaly chips with sheen when wet			EC: 1044uS/cm, pH: 7.6, Temp: 29.6C, orange-brown, opaque		
						EC: 1091uS/cm, pH: 7.5, Temp: 29.5C, orange-brown, opaque		
						EC: 1025uS/cm, pH: 7.51, Temp: 30.1C, orange-brown, opaque		
						EC: 1056uS/cm, pH: 7.41, Temp: 29.8C, brown-grey, opaque, slight sheen		
						EC: 1118uS/cm, pH: 7.42, Temp: 29.8C, dark grey, opaque, sheen		

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COMPOSITE WELL LOG

Bore No: MDPB0019

Client: Roy Hill

Project: Mulga East PFS Investigations

Commenced: 6/09/2021
Completed: 10/09/2021
Drilled: Pentium Hydro
Logged By: A.S

Method: DR / DTH
Fluid: Air
Bit Record: 0-52m = 432mm
59-77m = 368mm

Area: Mulga East
GL Elevation: 423.16mAHD
Easting: 661995
Northing: 7552117
Projection: MGA94_Z50

Static Water Level: 22.05 mbtoc
Date: 15/09/2021

Remarks: PVC stick up = 0.54

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Drilling Yield (L/s)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0 – 80	Undiff; CID Pisolite; Marra Mamba		Gravel: Red-brown silt and clay with hematite and goethite chips. Minor maghemite pisolites, moderately sorted 1-4mm diameter.			AWT- Injecting	0-8m = cement seal	
			CID: Yellow goethitic chips, vuggy goethite clasts, minor hematite, angular hard cloudy grey chert.			AWT- Injecting	8-9m = bentonite seal	
			BIF: Red-brown, vuggy goethite clasts, siliceous red/yellow/blue-grey BIF wiith chert bands, poorly sorted.			AWT- Injecting	Blank PVC CL12, 250mm	
			BIF: Yellow-brown clay, blue-grey and yellow banded goethitic BIF, red-purple hematitic shale.			AWT- Injecting		
			Shale: Red-purple to brown clay, increase in chips size, hematitic shales with red streak, minor BIF.			Brown, EC: 772 uS/cm, pH: 7.94, Temp: 31.6°C		
			Chert: Dark grey/black, brown stained , hard angular fragments. Pink clay band at 26m.			Dark Brown, EC: 531 uS/cm, pH: 8.01, Temp: 29.7°C	9-77m = gravel pack (3.2-6.4mm)	
			Chert: Red/maroon chert interbedded with dark red shales.			Dark Brown, EC: 726 uS/cm, pH: 7.82, Temp: 30.3°C		
						Dark Brown/Red, EC: 701 uS/cm, pH: 7.96, Temp: 31.0°C	17-77m = 250mm Slotted PVC CL12, 1mm aperture	
			Shale: Black, soft shale with abundant pyrite from 60m.			Dark Brown/Red, EC: 710 uS/cm, pH: 7.74, Temp: 30.9°C		
						Light Brown, EC: 710 uS/cm, pH: 7.77, Temp: 30.3°C		
						Dark Grey/Black, EC: 702 uS/cm, pH: 7.96, Temp: 28.6°C		
						Dark Grey/Black, EC: 722 uS/cm, pH: 7.98, Temp: 29.0°C		
						Dark Grey/Black, EC: 721 uS/cm, pH: 7.99, Temp: 29.9°C		

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COMPOSITE WELL LOG

Bore No: MDPB0020

Client: Roy Hill

Project: Mulga East PFS Investigations

Commenced: 2/11/2021
Completed: 13/11/2021
Drilled: Pentium Hydro
Logged By: A.S

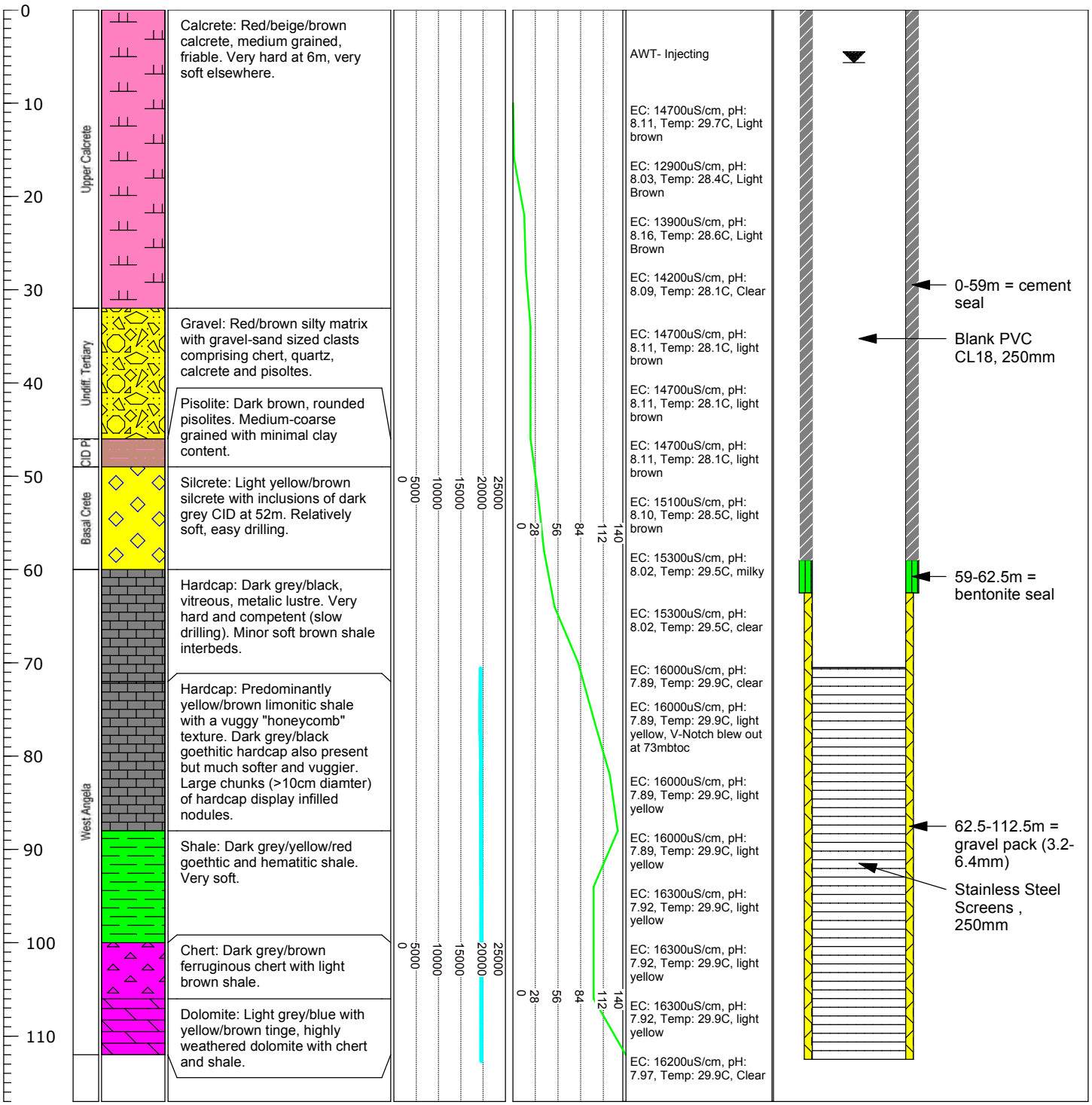
Method: DR / DTH
Fluid: Air
Bit Record: 0-106m = 432mm
106-112.5m = 368mm

Area: Malay Well
GL Elevation: 404.68 mAHD
Easting: 654423
Northing: 7546694
Projection: MGA94_Z50

Static Water Level: 5.66 mBTOC
Date: 18/11/2021

Remarks: PVC stick up = 0.54

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Drilling Yield (L/s)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0 – 30	Upper Calcrete		Calcrete: Red/beige/brown calcrete, medium grained, friable. Very hard at 6m, very soft elsewhere.			AWT- Injecting		
30 – 40	Undiff. Tertiary		Gravel: Red/brown silty matrix with gravel-sand sized clasts comprising chert, quartz, calcrete and pisoltes.			EC: 14700uS/cm, pH: 8.11, Temp: 29.7C, Light brown EC: 12900uS/cm, pH: 8.03, Temp: 28.4C, Light Brown EC: 13900uS/cm, pH: 8.16, Temp: 28.6C, Light Brown EC: 14200uS/cm, pH: 8.09, Temp: 28.1C, Clear		
40 – 50	CID P		Pisolite: Dark brown, rounded pisolites. Medium-coarse grained with minimal clay content.			EC: 14700uS/cm, pH: 8.11, Temp: 28.1C, light brown EC: 14700uS/cm, pH: 8.11, Temp: 28.1C, light brown	0-59m = cement seal Blank PVC CL18, 250mm	
50 – 60	Basal Crete		Silcrete: Light yellow/brown silcrete with inclusions of dark grey CID at 52m. Relatively soft, easy drilling.			EC: 14700uS/cm, pH: 8.11, Temp: 28.1C, light brown EC: 15100uS/cm, pH: 8.10, Temp: 28.5C, light brown		
60 – 70	West Angela		Hardcap: Dark grey/black, vitreous, metalic lustre. Very hard and competent (slow drilling). Minor soft brown shale interbeds.			EC: 15300uS/cm, pH: 8.02, Temp: 29.5C, milky EC: 15300uS/cm, pH: 8.02, Temp: 29.5C, clear	59-62.5m = bentonite seal	
70 – 80			Hardcap: Predominantly yellow/brown limonitic shale with a vuggy "honeycomb" texture. Dark grey/black goethitic hardcap also present but much softer and vuggier. Large chunks (>10cm diamter) of hardcap display infilled nodules.			EC: 16000uS/cm, pH: 7.89, Temp: 29.9C, clear EC: 16000uS/cm, pH: 7.89, Temp: 29.9C, light yellow, V-Notch blew out at 73mbtoc		
80 – 90			Shale: Dark grey/yellow/red goethtic and hematitic shale. Very soft.			EC: 16000uS/cm, pH: 7.89, Temp: 29.9C, light yellow EC: 16000uS/cm, pH: 7.89, Temp: 29.9C, light yellow EC: 16300uS/cm, pH: 7.92, Temp: 29.9C, light yellow	62.5-112.5m = gravel pack (3.2-6.4mm) Stainless Steel Screens , 250mm	
90 – 100			Chert: Dark grey/brown ferruginous chert with light brown shale.			EC: 16300uS/cm, pH: 7.92, Temp: 29.9C, light yellow EC: 16300uS/cm, pH: 7.92, Temp: 29.9C, light yellow		
100 – 110			Dolomite: Light grey/blue with yellow/brown tinge, highly weathered dolomite with chert and shale.			EC: 16200uS/cm, pH: 7.97, Temp: 29.9C, Clear		



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COMPOSITE WELL LOG

Bore No: MDPB0021

Client: Roy Hill/ HanRoy
Project: Mulga Downs EPFS

Commenced:	18/08/2023	**Method:**	DR / DTH	**Area:**	Malay Well
Completed:	20/09/2023	**Fluid:**	Air	**GL Elevation:**	TBC
Drilled:	Pentium Hydro	**Bit Record:**	0-100m = 479mm	**Easting:**	643992
Logged By:	SP/AE		100-124m = 419mm	**Northing:**	7550206
				Projection:	MGA94 Zone 50
Static Water Level:	5.20 mbtoc	**Date:**	23/09/2023	**Remarks:**	Stick up= 0.435m

Depth (mbgl)	Strat / Hydro	Graphic Log	Lithological Description	EC Profile (µS/cm)	Drilling Yield (L/s)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0	Upper Calcrete		Clay: Red-brown, slightly sandy gravelly clay. Sand is of black colouration and sub angular.			Adjacent to MDPZ9215D+S		
10			Calcrete: Pale brown to cream mottled green in places. Increasing BIF inclustions with depth. Reacts strongly with HCl.			EC: 2167 uS/cm, pH: 7.79 Yellow/brown, v high turbidity		
20						EC: 3640 uS/cm, pH: 7.81 Brown. High turbidity		
	Undiff Tertiary		Gravel and Sand: Red brown clayey, slightly gravelly sand. Sand and gravel consist of sub-angular chert, calcrete, shale and pisolites.			EC: 4260, pH: 8.05 Pale brown. Moderate turbidity	Cement/ Bentonite Grout (1.2-38.7m)	
30			Gravel and Sand: Red-brown gravel and sand with clay. Sand and gravel is of banded chert.			EC: 3500 uS/cm, pH: 8.35 Moderate turbidity. Pale brown	300mm CL18 Blank PVC Casing (0-47m)	
			Gravel and Sand: Red-brown gravel and sand with clay. Angular to rounded cherts, with some large fragments over 3cm in length.			EC: 3390 uS/cm, pH: 8.39 Moderate-high turbidity. Pale brown		
40						EC: 3340, pH: 8.29 Moderate turbidity. Red brown	Bentonite Seal (38.7-40.6m)	
50	Basal Crete		Calcrete: Orange-brown clay mixed with white-grey calcrete and minor BIF. Calcrete vuggy and highly effervesent . Moderately hard (breakable with hammer blow). Chip size between 1-30mm.			EC: 3028, pH: 8.38 Moderate turbidity. Red brown		
						2.5L/s added, to measured flow to compensate for flow around v-notch (grout failure). EC: 5780, pH: 8.16		
60			Calcrete: White mottled dark green and pink-brown. Effervesent when crushed. Yellow-brown goethite staining. Very hard (takes several hammer blows to break).			2.5 L/s added, to measured flow to compensate for flow around v-notch (grout failure). EC: 4930, pH: 8.04, Pale brown low to moderate turbidity	300mm Stainless Steel Screen (47-71m)	
			Hardcap: Grey-black, vitreous and vuggy. Reworked CID/hardcap with orange-white calcrete. Yellow-brown goethitic staining on CID			5 L/s added, to measured flow to compensate for flow around v-notch (grout failure). EC: 5890, pH: 8.05 Pale brown, low to moderate turbidity.		
70	West Angelas		Shale: Grey mottled yellow brown shale with hardcap and weathered puggy goethitic clay. Very low strength.			5 L/s added, to measured flow to compensate for flow around v-notch (grout failure). EC: 6840, pH: 8.11 Pale brown, low to moderate turbidity	Graded Gravel Pack (40.6-124m)	
80			BIF: Light grey. BIF - evidence of mineralisation with goethite and haematite. Grey and goethitic yellow clay and red shale. Non magnetic.			5 L/s added, to measured flow to compensate for flow around v-notch (grout failure) water flowing around side of v-notch. EC: 6990, pH: 8.07 Low-moderate turbidity. Pale brown.		
90								

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COMPOSITE WELL LOG

Bore No: MDPB0021

Client: Roy Hill/ HanRoy
Project: Mulga Downs EPFS

Commenced:	18/08/2023	**Method:**	DR / DTH	**Area:**	Malay Well
Completed:	20/09/2023	**Fluid:**	Air	**GL Elevation:**	TBC
Drilled:	Pentium Hydro	**Bit Record:**	0-100m = 479mm	**Easting:**	643992
Logged By:	SP/AE		100-124m = 419mm	**Northing:**	7550206
				Projection:	MGA94 Zone 50
Static Water Level:	5.20 mbtoc	**Date:**	23/09/2023	**Remarks:**	Stick up= 0.435m

Depth (mbgl)	Strat / Hydro	Graphic Log	Lithological Description	EC Profile (µS/cm)	Drilling Yield (L/s)	Field Notes	Well Completion: Diagram	Well Completion: Notes
100	West Angelas		BIF: Red-brown. BIF and chert with red shale and white clay. Non magnetic.			5 L/s added , to measured flow to compensate for flow around v-notch (grout failure). EC: 7010. pH: 7.95 Moderate turbidity. Brown.	300mm CL18 Blank PVC Casing (71-112m)	
110			Chert: Dark grey. Chert, BIF and shale in a dark grey clay matrix. Evidence of yellow/brown goethitic staining. Non magnetic.			5 L/s added, to measured flow to compensate for flow around v-notch (grout failure). EC: 6960, pH: 7.58 Low turbidity, pale brown.		
120			Chert: Light grey chert with red shale and BIF - evidence yellow/brown goethitic staining. Non magnetic.			V-notch removed, excessive flows of water in discharge trench. Flow estimated by judging outflow from cyclone. EC: 7070 uS/cm, pH: 8.06. Moderate turbidity. Brown.	Graded Gravel Pack (40.6-124m)	
130			Chert: Dark grey manganiferous chert with shale. Very hard. Non magnetic.			DR casing re-ran @98m bgl. By-eye. Not enough water to sample. Ground Getting Harder @114 EOH @ 125m	300mm Stainless Steel Screen (112-124m)	

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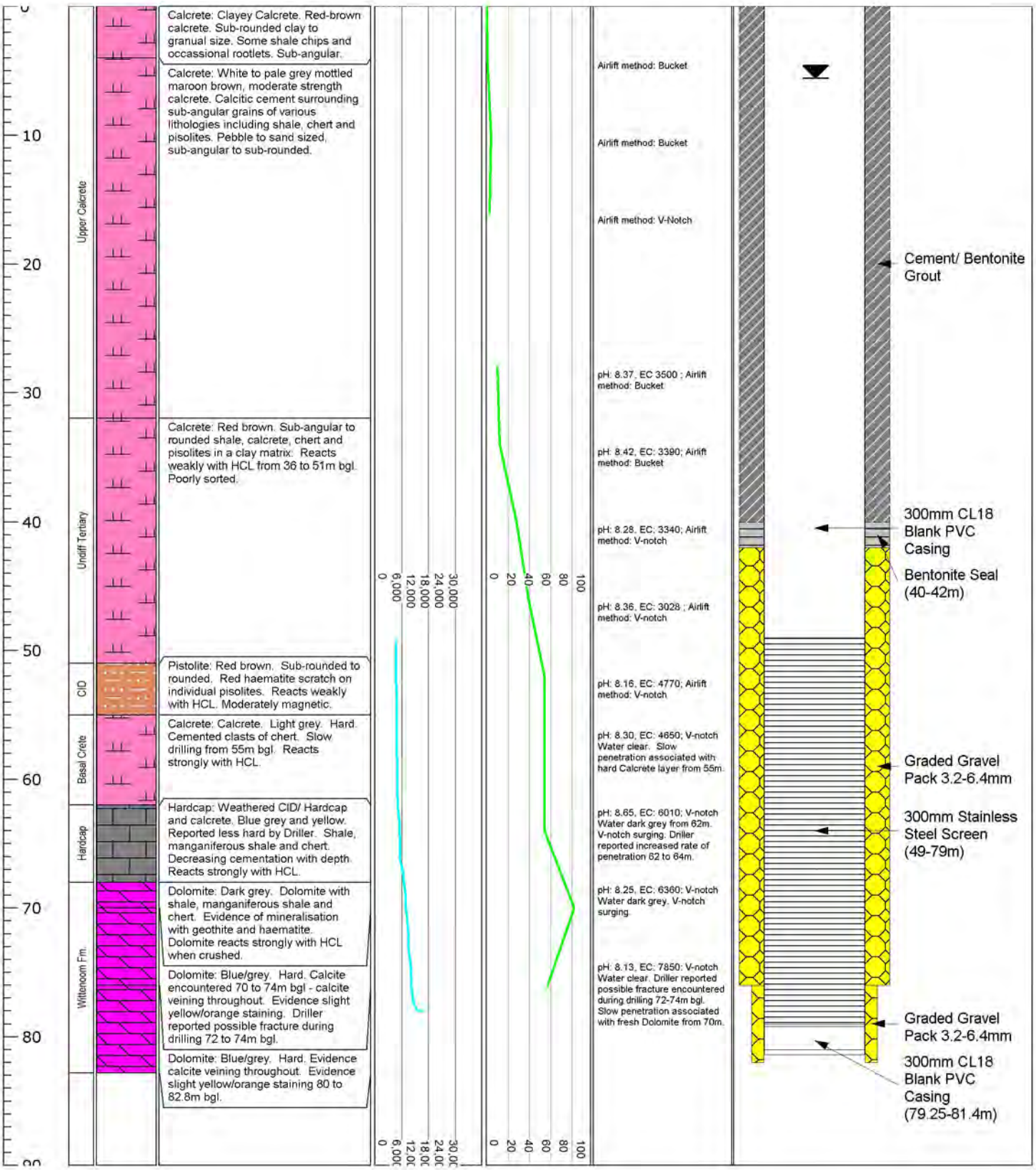
COMPOSITE WELL LOG

Bore No: MDPB0022

Client: Roy Hill / Han Roy
Project: Mulga Downs EPFS

Commenced:	30/09/2023	**Method:**	DR / DTH	**Area:**	Malay Well
Completed:	10/10/2023	**Fluid:**	Air	**GL Elevation:**	tbc
Drilled:	Pentium Hydro	**Bit Record:**	0-76m = 479mm	**Easting:**	648819
Logged By:	SP/AE		76-82m = 419mm	**Northing:**	7546180
				Projection:	GDA94 Zone 50
Static Water Level:	5.55 mbtoc	**Date:**	16/10/2023	**Remarks:**	Stick-up= 0.65m

Depth (mbgl)	Strat / Hydro	Graphic Log	Lithological Description	EC Profile (µS/cm)	Drilling Yield (L/s)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0–30	Upper Calcrete		Calcrete: Clayey Calcrete. Red-brown calcrete. Sub-rounded clay to granual size. Some shale chips and occassional rootlets. Sub-angular.			Airlift method: Bucket		
			Calcrete: White to pale grey mottled maroon brown, moderate strength calcrete. Calcitic cement surrounding sub-angular grains of various lithologies including shale, chert and pisolites. Pebble to sand sized, sub-angular to sub-rounded.			Airlift method: Bucket Airlift method: V-Notch		
30–50	Undiff Tertiary		Calcrete: Red brown. Sub-angular to rounded shale, calcrete, chert and pisolites in a clay matrix: Reacts weakly with HCL from 36 to 51m bgl. Poorly sorted.			pH: 8.37, EC 3500 ; Airlift method: Bucket pH: 8.42, EC: 3390; Airlift method: Bucket pH: 8.28, EC: 3340; Airlift method: V-notch		
50–60	CID		Pistolite: Red brown. Sub-rounded to rounded. Red haematite scratch on individual pisolites. Reacts weakly with HCL. Moderately magnetic.					
	Basal Crete		Calcrete: Calcrete. Light grey. Hard. Cemented clasts of chert. Slow drilling from 55m bgl. Reacts strongly with HCL.			pH: 8.36, EC: 3028 ; Airlift method: V-notch pH: 8.16, EC: 4770; Airlift method: V-notch pH: 8.30, EC: 4650; V-notch Water clear. Slow penetration associated with hard Calcrete layer from 55m.		
60–70	Hardcap		Hardcap: Weathered CID/ Hardcap and calcrete. Blue grey and yellow. Reported less hard by Driller. Shale, manganiferous shale and chert. Decreasing cementation with depth. Reacts strongly with HCL.			pH: 8.65, EC: 6010; V-notch Water dark grey from 62m. V-notch surging. Driller reported increased rate of penetration 62 to 64m.		
70–80	Wittenoom Fm.		Dolomite: Dark grey. Dolomite with shale, manganiferous shale and chert. Evidence of mineralisation with geothite and haematite. Dolomite reacts strongly with HCL when crushed.			pH: 8.25, EC: 6360; V-notch Water dark grey. V-notch surging.		
			Dolomite: Blue/grey. Hard. Calcite encountered 70 to 74m bgl - calcite veining throughout. Evidence slight yellow/orange staining. Driller reported possible fracture during drilling 72 to 74m bgl.			pH: 8.13, EC: 7850; V-notch Water clear. Driller reported possible fracture encountered during drilling 72-74m bgl. Slow penetration associated with fresh Dolomite from 70m.		
80–82			Dolomite: Blue/grey. Hard. Evidence calcite veining throughout. Evidence slight yellow/orange staining 80 to 82.8m bgl.					



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COMPOSITE WELL LOG

Bore No: MDPZ7449A

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 10/11/2018
Completed: 14/11/2018
Drilled: Ausdrill NW
Logged By: TV

Method: DR / DTH
Fluid: Air
Bit Record: 0-52m = 241mm
52-82m = 191mm

Area: Mulga Downs
Elevation: 404 mAHD
Easting: 655657
Northing: 7551787
Projection: MGA94 Zone 50

Static Water Level: 4.71 mbtoc **Date:** 18/11/18

Remarks: Stick up = 0.54m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion Diagram	Well Completion Notes
0 – 100	Alluvium; Upper Calcrete; Undiff. Tertiary; CID/Pisolite; Marra Mamba; Jerinah		Alluvium: Red-brown to brown, poorly-sorted, weathered, mixed rock fragments in a silty-clay matrix Calcrete: White, vuggy, subangular calcrete with red-brown clay towards top and grey, angular chert towards base Pisolite: Red-brown to dark-grey, rounded, hard, strongly-magnetic in a clay matrix with minor subangular fragments of chert and BIF Pisolite/Clay: Dark, red-brown, rounded, hard, strongly-magnetic pisolites with soft red-brown clay increasing towards base CID/Hardcap: Red-brown to yellow-brown and dark-grey, porous, vuggy, strongly weathered limonitic ore Pisolite/Shale: Yellow-brown and brown, vuggy, porous, strongly weathered, limonitic and goethitic, low-grade ore and shale Clay: Yellow and green, sticky, plastic, completely weathered puggy clay Chert: Dark-grey, purple and white, fresh, hard, bedded chert with minor siltstone and shale. Shale largely altered to clay Chert: Dark-grey, hard, brittle subangular, fine-grained chert Shale: Purple, soft, strongly weathered shale interbedded with dark-grey, hard, subangular chert Shale: Black, well-bedded, fresh, carbonaceous shale with minor red-brown, angular chert bands	0 – 25,000 (0, 5000, 10000, 15000, 20000, 25000)	Adjacent to MDPB0012 FWS @ 8m, Airlift: 0.2L/s, EC: 1476uS/cm Airlift: 4.0L/s, EC: 1487uS/cm, pH: 8.12, Brown Airlift: 1.0L/s, EC: 1031uS/cm, pH: 7.87, Brown Airlift: 0.3L/s, Too muddy to sample Airlift: 0.9L/s, EC: 1080uS/cm, pH: 7.93 Airlift: 1.6L/s, EC: 1810uS/cm, pH: 8.25, Light Brown Airlift: 12.0L/s est, EC: 2034uS/cm, pH: 7.86, Yellow-Brown Airlift: 2.7L/s, EC: 3740uS/cm, pH: 8.10, White Airlift: 3.0L/s, EC: 4620uS/cm, pH: 8.23, Light-Pink/White Airlift: 3.5L/s, EC: 5580uS/cm, pH: 8.13, Light Grey Airlift: 4.0L/s, EC: 5100uS/cm, pH: 8.37, Light Grey Airlift: 9.0L/s, EC: 2950uS/cm, pH: 8.23, Very Light Grey Airlift: 15.0L/s est, EC: 2480uS/cm, pH: 8.02, Dark Grey	0-49.5 = cement/bentonite grout 50mm CL18 PVC Blank Casing 49.5-52m = bentonite seal 50mm CL18 PVC Slotted Casing (2mm slots) 52-82m = gravel pack (3.2-6.4mm)	

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COMPOSITE WELL LOG

Bore No: MDPZ7449B

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 14/11/2018
Completed: 16/11/2018
Drilled: Ausdrill NW
Logged By: TV

Method: DR / DTH
Fluid: Air
Bit Record: 0-46m = 241mm
46-52m = 191mm

Area: Mulga Downs
Elevation: 404 mAHD
Easting: 655657
Northing: 7551787
Projection: MGA94 Zone 50

Static Water Level: 5.09 mbtoc **Date:** 18/11/18

Remarks: Stick up = 0.56m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion Diagram	Well Completion Notes
0	Upper Cal/Alluvi		Alluvium: Red-brown to brown, poorly-sorted. Mainly clay/silt with angular fragments of chert and quartz	0 – 25,000	Adjacent to MDPB0012	0-9m = cement/bentonite grout	
10	Undiff Tertiary		Calcrete: White and light-brown, friable, vuggy, unstructured calcrete		FWS @ 6m, Airlift: 0.1L/s, Muddy, Pink	0-11m = 50mm CL18 PVC Blank Casing	
			Clayey Gravel: Red-brown to dark-grey, rounded, strongly magnetic, pisolites in a clay matrix with subrounded clasts of chert		Airlift: 0.2L/s, Muddy	9-10m = bentonite seal	
20			Pisolite/Clay: Red-brown to dark-grey, well-rounded, well-sorted pisolites with minor clay and clasts mainly of chert				
30	CID Pisolite				Airlift: 0.5L/s, Muddy	10-47m = gravel pack (3.2-6.4mm)	
					Airlift: 2.0L/s, EC: 3200uS/cm, pH: 8.19, Muddy, Brown	11-47m = 50mm CL18 PVC Slotted Casing (2mm slots)	
40			CID/Hardcap: Dark-brown to grey-brown, hard, vuggy, porous, strongly weathered with limonite and goethite		Airlift: 4.0L/s, EC: 9400uS/cm, pH: 8.22, Light Brown		
			CID/Hardcap: Yellow-brown and brown, vuggy, porous, strongly limonitic with minor grey shale		Airlift: 12.0L/s est, EC: 11900uS/cm, pH: 8.10, Light Brown		
50				0 5000 10000 15000 20000 25000		47-52 = Fallback	
					Airlift: 15.0L/s est, EC: 1357uS/cm, pH: 7.91, Light Brown		
60							
70							
80							
90							
100							

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COMPOSITE WELL LOG

Bore No: MDPZ7449C

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 16/11/2018
Completed: 17/11/2018
Drilled: Ausdrill NW
Logged By: TV

Method: DR
Fluid: Air
Bit Record: 0-11m = 241mm

Area: Mulga Downs
Elevation: 404 mAHD
Easting: 655657
Northing: 7551787
Projection: MGA94 Zone 50

Static Water Level: 5.06 mbtoc **Date:** 18/11/18

Remarks: Stick up = 0.54m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0	Alluvi		Alluvium: Red-brown to brown, poorly-sorted. Mainly clay/silt with angular fragments of chert and quartz	0 – 25,000	Adjacent to MDPB0012	0-2 = backfill	
10	Upper Calcrete		Calcrete: White and light-brown, friable, vuggy, unstructured calcrete		FWS @ 6m, Airlift: 0.1L/s, EC: 576uS/cm, pH: 8.3, Pink	50mm CL18 PVC Blank Casing	
	Undif		Silcrete: light-brown, friable,		Airlift: 0.1L/s, EC: 485uS/cm, pH: 8.19, Muddy	2-3m = bentonite seal	
			Clayey Gravel: Red-brown to dark-grey, rounded, strongly magnetic, pisolites in a clay matrix with subrounded clasts of chert			3-11m = gravel pack (3.2-6.4mm)	
100				0, 5000, 10000, 15000, 20000, 25000		50mm CL18 PVC Slotted Casing Fallback	

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COMPOSITE WELL LOG

Bore No: MDPZ7450A

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 17/11/2018
Completed: 20/11/18
Drilled: Ausdrill NW
Logged By: JJ

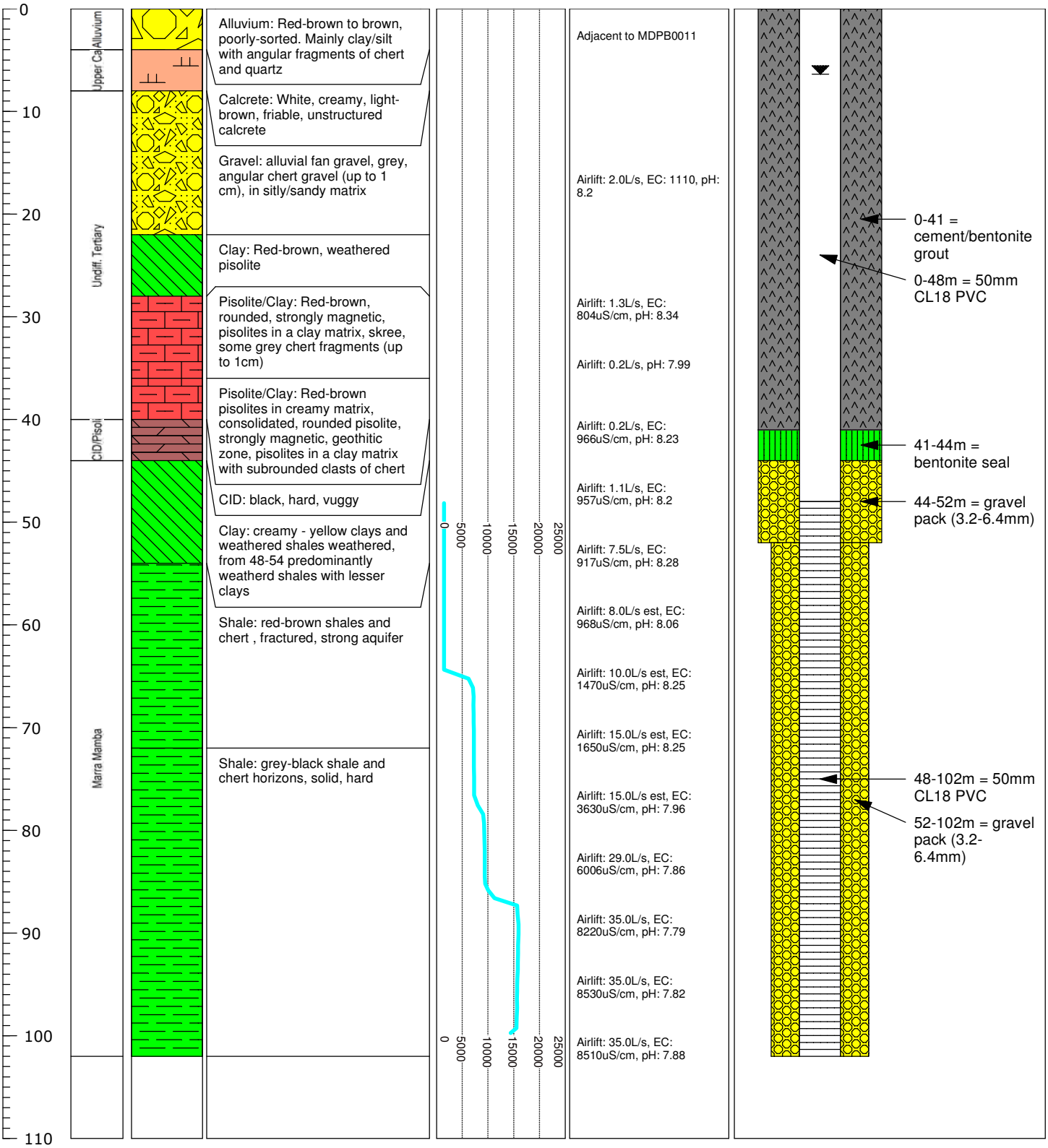
Method: DR / DTH
Fluid: Air
Bit Record: 0-52m = 241mm
52-102m = 191mm

Area: Mulga Downs
Elevation: 403 mAHD
Easting: 652219
Northing: 7552541
Projection: MGA94 Zone 50

Static Water Level: 6.38 mbtoc **Date:** 23/11/18

Remarks: Stick up = 0.59m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion Diagram	Well Completion Notes
0–10	Alluvium / Upper Ca		Alluvium: Red-brown to brown, poorly-sorted. Mainly clay/silt with angular fragments of chert and quartz		Adjacent to MDPB0011		
10–20	Alluvium / Upper Ca		Calcrete: White, creamy, light-brown, friable, unstructured calcrete		Airlift: 2.0L/s, EC: 1110, pH: 8.2		
20–30	Undiff. Tertiary		Gravel: alluvial fan gravel, grey, angular chert gravel (up to 1 cm), in sitly/sandy matrix		Airlift: 1.3L/s, EC: 804uS/cm, pH: 8.34		
30–40	Undiff. Tertiary		Clay: Red-brown, weathered pisolite		Airlift: 0.2L/s, pH: 7.99		
40–50	CID/Pisoli		Pisolite/Clay: Red-brown, rounded, strongly magnetic, pisolites in a clay matrix, skree, some grey chert fragments (up to 1cm)		Airlift: 0.2L/s, EC: 966uS/cm, pH: 8.23		
50–60	CID/Pisoli		Pisolite/Clay: Red-brown pisolites in creamy matrix, consolidated, rounded pisolite, strongly magnetic, geothitic zone, pisolites in a clay matrix with subrounded clasts of chert		Airlift: 1.1L/s, EC: 957uS/cm, pH: 8.2		
60–70	CID/Pisoli		CID: black, hard, vuggy		Airlift: 7.5L/s, EC: 917uS/cm, pH: 8.28		
70–80	Marra Mamba		Clay: creamy - yellow clays and weathered shales weathered, from 48-54 predominantly weatherd shales with lesser clays		Airlift: 8.0L/s est, EC: 968uS/cm, pH: 8.06		
80–90	Marra Mamba		Shale: red-brown shales and chert , fractured, strong aquifer		Airlift: 10.0L/s est, EC: 1470uS/cm, pH: 8.25		
90–100	Marra Mamba				Airlift: 15.0L/s est, EC: 1650uS/cm, pH: 8.25		
100–110	Marra Mamba		Shale: grey-black shale and chert horizons, solid, hard		Airlift: 15.0L/s est, EC: 3630uS/cm, pH: 7.96		
					Airlift: 29.0L/s, EC: 6006uS/cm, pH: 7.86		
					Airlift: 35.0L/s, EC: 8220uS/cm, pH: 7.79		
					Airlift: 35.0L/s, EC: 8530uS/cm, pH: 7.82		
					Airlift: 35.0L/s, EC: 8510uS/cm, pH: 7.88		



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COMPOSITE WELL LOG

Bore No: MDPZ7450B

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 20/11/2018
Completed: 22/11/2018
Drilled: Ausdrill NW
Logged By: JJ

Method: DR / DTH
Fluid: Air
Bit Record: 0-40m = 241mm
40-42m = 191mm

Area: Mulga Downs
Elevation: 403 mAHD
Easting: 652219
Northing: 7552541
Projection: MGA94 Zone 50

Static Water Level: 6.17 mbtoc
Date: 24/11/2018
Remarks: Stick up = 0.61m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion Diagram	Well Completion Notes
0	Alluvium		Alluvium: Red-brown to brown, poorly-sorted. Mainly clay/silt with angular fragments of chert and quartz	0 – 25,000	Adjacent to MDPB0011	0-18 = cement/bentonite grout	
10	Upper Ca		Calcrete: White, creamy, light-brown, friable, unstructured calcrete			0-22m = 50mm CL18 PVC	
20	Undiff. Tertiary		Gravel: alluvial fan gravel, grey, angular chert gravel (up to 1 cm), in silty/sandy matrix , water strikes		Airlift: 0.5L/s, EC: 1279uS/cm, pH: 8.32, Dirty	18-20m = bentonite seal	
30			Clay: Red-brown, weathered pisolite		Airlift: 2.5L/s, EC: 2328uS/cm, pH: 8.11, Dirty		
40	CID/Pisoli		Pisolite/Clay: Red-brown, rounded, strongly magnetic, pisolites in a clay matrix, skree, some grey chert fragments (up to 1cm)		Airlift: 3.0L/s, EC: 1126uS/cm, pH: 8.41, Clean	20-40m = gravel pack (3.2-6.4mm)	
50			Pisolite/Clay: Red-brown pisolites in creamy matrix, consolidated, rounded pisolite, strongly magnetic, geothitic zone, pisolites in a clay matrix with subrounded clasts of chert		Airlift: 0.1L/s, Muddy	22-42m = 50mm CL18 PVC	
60			CID: black, hard, vuggy, lots of water		Airlift: 0.1L/s, Muddy		
70					Airlift: 5.0L/s, EC: 1412uS/cm, pH: 8.3, Clean	40-42m = gravel pack (3.2-6.4mm)	
80							
90							
100							
110							

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COMPOSITE WELL LOG

Bore No: MDPZ7450C

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 22/11/2018
Completed: 23/11/2018
Drilled: Ausdrill NW
Logged By: JJ

Method: DR
Fluid: Air
Bit Record: 0-22m = 241mm

Area: Mulga Downs
Elevation: 403 mAHD
Easting: 652219
Northing: 7552541
Projection: MGA94 Zone 50

Static Water Level: 6.21 mbtoc **Date:** 25/11/2018

Remarks: Stick up = 0.58m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0	Alluvium		Alluvium: Red-brown to brown, poorly-sorted. Mainly clay/silt with angular fragments of chert and quartz	0 – 25,000	Adjacent to MDPB0011	0-6 = cement/bentonite grout 0-10m = 50mm CL18 PVC 6-8m = bentonite seal 8-22m = gravel pack (3.2-6.4mm) 10-22m = 50mm CL18 PVC	
10	Upper Ca		Calcrete: White, creamy, light-brown, friable, unstructured calcrete				
20	Undiff. Tertiary		Gravel: alluvial fan gravel, grey, angular chert gravel (up to 6 cm), in silty/sandy matrix , water strikes		Airlift: 0.5L/s est Airlift: 5.0L/s est, EC: 914uS/cm, pH: 8.3		
30							
40							
50				0, 5000, 10000, 15000, 20000, 25000			
60							
70							
80							
90							
100				0, 5000, 10000, 15000, 20000, 25000			
110							

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COMPOSITE WELL LOG

Bore No: MDPZ7451A

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 23/11/2018
Completed: 27/11/2018
Drilled: Ausdrill NW
Logged By: JJ

Method: DR / DTH
Fluid: Air
Bit Record: 0-118m = 241mm
118-120m = 191mm

Area: Mulga Downs
Elevation: 404 mAHD
Easting: 651347
Northing: 7550579
Projection: MGA94 Zone 50

Static Water Level: 4.34 mbtoc **Date:** 30/11/2018

Remarks: Stick up: 0.53m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion Diagram	Well Completion Notes
0–130	Upper Calcrete; Undiff. Tertiary; Basal Calcrete; Marra Mamba		Alluvium: Red, with some angular grey chert pebbles Calcrete: creamy brown, some vugs, but generally massive, limited water flow Clay: red, with angular chert pebbles Gravel: alluvial fan gravel. Alternating gravel, gravel in clay matrix and clay horizons, some strong inflow with gravel, clay content increasing with depth Ferricrete: red-black, vuggy, fine-medium, moderately sorted Calcrete: white to creamy, looks like dolomite, vuggy in places, some water inflow Chert: vuggy, red-brown Clay: white-light grey, saprolitic clay, bentonite-like Clay: creamy green, saprolitic clay with pink staining/layers Clay: pinkish saprolitic clay with alternating lenses of ferricrete Hardcap: red-brown, water inflow, vuggy, fine-medium, moderately sorted Shale: lesser siltstone layers, grey brown, strong water inflow Shale: black-grey, oily water flow Shale: brown-grey, some cherty layers Shale: black (soft & oily) to grey Shale: black (soft & oily) to grey	0 5000 10000 15000 20000 25000	Airlift: 0.5L/s Airlift: 0.0L/s est Airlift: 1.0L/s, EC: 2904uS/cm, pH: 8.0 Airlift: 0.0L/s est, Muddy Airlift: 0.1L/s est, EC: 1259uS/cm, pH: 8.13 Airlift: 0.3L/s, EC: 1346uS/cm, pH: 8.16 Airlift: 0.5L/s, EC: 6540uS/cm, pH: 7.99 Airlift: 0.1L/s est, EC: 2243uS/cm, pH: 8.55, Muddy Airlift: 7.1L/s, EC: 15620uS/cm, pH: 7.99 Airlift: 1.5L/s, EC: 3660uS/cm, pH: 8.62 Airlift: 2.0L/s, EC: 2227uS/cm, pH: 8.71 Airlift: 0.1L/s est, EC: 1712uS/cm, pH: 8.08, Muddy Airlift: 0.0L/s est, Muddy Airlift: 0.0L/s est, Muddy Airlift: 0.0L/s est, Muddy Airlift: 12.0L/s, EC: 7900uS/cm, pH: 7.79 Airlift: 15.0L/s, EC: 9240uS/cm, pH: 7.74 Airlift: 20.0L/s est, EC: 9730uS/cm, pH: 8.34 Airlift: 25.0L/s, EC: 9790uS/cm, pH: 8.18 Airlift: 25L/s est, EC: 10030uS/cm, pH: 8.17 120m: Airlift: 25L/s est, EC: 1273uS/cm, pH: 7.86	0-90 = cement/bentonite grout 0-94m = 50mm CL18 PVC Blank Casing 90-92m = bentonite seal 92-118m = gravel pack (3.2-6.4mm) 94-120m = 50mm CL18 PVC Slotted Casing (2mm slots) 118-120m = gravel pack (3.2-6.4mm)	

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COMPOSITE WELL LOG

Bore No: MDPZ7451B

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 28/11/2018
Completed: 01/12/2018
Drilled: Ausdrill NW
Logged By: ATS

Method: DR
Fluid: Air
Bit Record: 0-64m = 241mm

Area: Mulga Downs
Elevation: 404 mAHD
Easting: 651337
Northing: 7550574
Projection: MGA94 Zone 50

Static Water Level: 4.18 mbtoc
Date: 02/12/2018
Remarks: Stick up = 0.54m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion Diagram	Well Completion Notes
0 – 130	Upper Cal / Undiff. Tertiary / Basal Calcrete		Alluvium: red/brown silty clay with medium grained angular chert lithics. Calcrete: white-beige, carbonaceous matrix with minor brown chert clasts Clay: red/brown silty clay with medium grained angular chert and magnetic lithics. Gravel: red/brown clay matrix with angular-subrounded chert (with minor quartz) gravel. Becoming mostly clay at 48m. Calcrete: red/pinky-beige, massive calcrete, becoming white-green/yellow at 58m. Ferricrete: black/brown ferricrete with minor calcrete at 63m.	0 – 25000	Airlift: 0.0L/s est, EC: 2620uS/cm, pH: 8.03 Airlift: 0.0L/s est, Muddy Airlift: 0.1L/s, EC: 1713uS/cm, pH: 8.03, Muddy Airlift: 0.5L/s, EC: 2590uS/cm, pH: 7.83, Muddy Airlift: 1.5L/s, EC: 1370uS/cm, pH: 8.00, Muddy Airlift: 0.5L/s, EC: 1710uS/cm, pH: 8.05 Airlift: 0.2L/s, EC: 2090uS/cm, pH: 8.16 Airlift: 2.5L/s, EC: 10420uS/cm, pH: 7.9 Airlift: 0.0L/s est, Muddy Airlift: 3.0L/s, EC: 15850uS/cm, pH: 7.75 Airlift: 0.0L/s est, EC: 4450uS/cm, pH: 8.28, Muddy	0-48 = cement/bentonite grout 0-52m = 50mm CL18 PVC Blank Casing 48-50m = bentonite seal 50-62m = gravel pack (3.2-6.4mm) 52-62m = 50mm CL18 PVC Slotted Casing (2mm slots) Backfill = 62-64m	

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COMPOSITE WELL LOG

Bore No: MDPZ7451C

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 02/12/2018
Completed: 03/12/2018
Drilled: Ausdrill NW
Logged By: ATS

Method: DR / DTH
Fluid: Air
Bit Record: 0-40m = 241mm
40-44m = 191mm

Area: Mulga Downs
Elevation: 404 mAHD
Easting: 651329
Northing: 7550568
Projection: MGA94 Zone 50

Static Water Level: 4.75 mbtoc **Date:** 10/12/2018

Remarks: Stick up: 0.53m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion Diagram	Well Completion Notes
0 – 130	Upper Cal / Undiff. Tertiary		Alluvium: red/brown silty clay with medium grained angular chert lithics. Calcrete: white-beige, carbonaceous matrix with minor brown chert clasts Clay: red/brown silty clay with medium grained angular chert and magnetic lithics. Gravel: red/brown clay matrix with angular-subrounded chert (with minor quartz) gravel. Becoming mostly clay at 48m.	0 – 25000		0-12 = cement/bentonite grout 0-14m = 50mm CL18 PVC Blank Casing 12-14m = bentonite seal 14-44m = 50mm CL18 PVC Slotted Casing (2mm slots) 14-44m = gravel pack (3.2-6.4mm)	

COMPOSITE WELL LOG

Bore No: MDPZ7452A

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Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 04/12/2018
Completed: 05/12/2018
Drilled: Ausdrill NW
Logged By: ATS

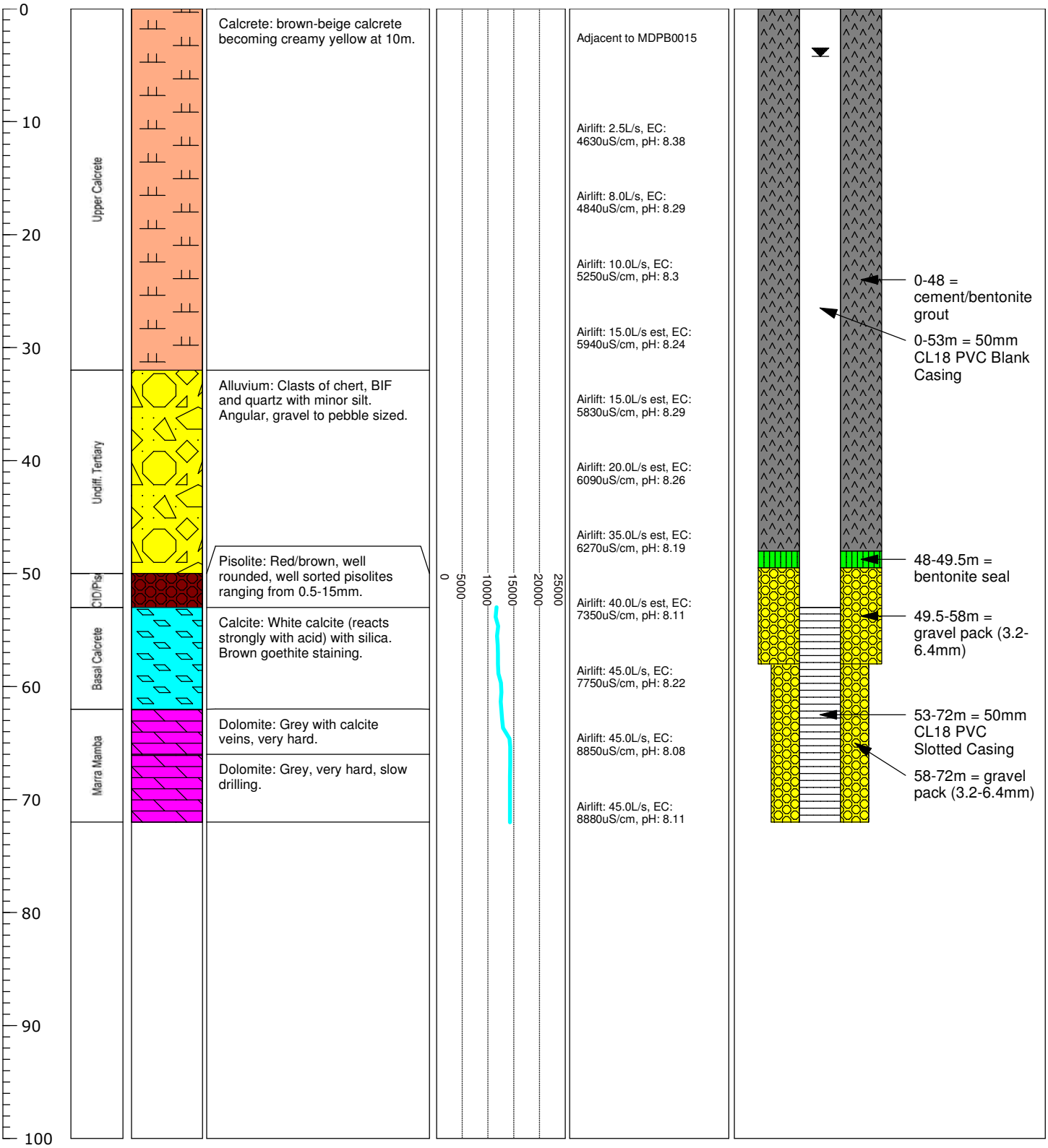
Method: DR / DTH
Fluid: Air
Bit Record: 0-58m = 241mm
58-72m = 191mm

Area: Mulga Downs
Elevation: 401 mAHD
Easting: 651326
Northing: 7545806
Projection: MGA94 Zone 50

Static Water Level: 4.22 mbgl **Date:** 10/12/2018

Remarks: Stick up: 0.60m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion Diagram	Well Completion Notes
0 – 30	Upper Calcrete		Calcrete: brown-beige calcrete becoming creamy yellow at 10m.		Adjacent to MDPB0015		
30 – 50	Undiff. Tertiary		Alluvium: Clasts of chert, BIF and quartz with minor silt. Angular, gravel to pebble sized.		Airlift: 2.5L/s, EC: 4630uS/cm, pH: 8.38 Airlift: 8.0L/s, EC: 4840uS/cm, pH: 8.29 Airlift: 10.0L/s, EC: 5250uS/cm, pH: 8.3 Airlift: 15.0L/s est, EC: 5940uS/cm, pH: 8.24 Airlift: 15.0L/s est, EC: 5830uS/cm, pH: 8.29 Airlift: 20.0L/s est, EC: 6090uS/cm, pH: 8.26 Airlift: 35.0L/s est, EC: 6270uS/cm, pH: 8.19	0-48 = cement/bentonite grout 0-53m = 50mm CL18 PVC Blank Casing	
50	CID/Pisl		Pisolite: Red/brown, well rounded, well sorted pisolites ranging from 0.5-15mm.			48-49.5m = bentonite seal	
50 – 60	Basal Calcrete		Calcite: White calcite (reacts strongly with acid) with silica. Brown goethite staining.		Airlift: 40.0L/s est, EC: 7350uS/cm, pH: 8.11 Airlift: 45.0L/s, EC: 7750uS/cm, pH: 8.22	49.5-58m = gravel pack (3.2-6.4mm)	
60 – 70	Marra Mamba		Dolomite: Grey with calcite veins, very hard. Dolomite: Grey, very hard, slow drilling.		Airlift: 45.0L/s, EC: 8850uS/cm, pH: 8.08 Airlift: 45.0L/s, EC: 8880uS/cm, pH: 8.11	53-72m = 50mm CL18 PVC Slotted Casing 58-72m = gravel pack (3.2-6.4mm)	



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COMPOSITE WELL LOG

Bore No: MDPZ7452B

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 06/12/2018
Completed: 07/12/2018
Drilled: Ausdrill NW
Logged By: ATS

Method: DR
Fluid: Air
Bit Record: 0-53m = 241mm

Area: Mulga Downs
Elevation: 401 mAHD
Easting: 651333
Northing: 7545806
Projection: MGA94 Zone 50

Static Water Level: 4.17 mbgl
Date: 10/12/2018
Remarks: Stick up: 0.61m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion Diagram	Well Completion Notes
0 – 25	Upper Calcrete		Silcrete: Light-grey, friable, vuggy, crystalline with visible quartz	0 – 25,000	Adjacent to MDPB0015	0-25m = cement/bentonite grout	
25 – 30	Upper Calcrete		Calcrete: Yellow-brown to light-yellow, friable, vuggy. Reacts strongly to acid		Airlift: 0.4L/s, EC: 5270uS/cm, pH: 8.27 Airlift: 2.0L/s, EC: 7050uS/cm, pH: 8.29	0-32.5m = 50mm CL18 PVC Blank Casing	
30 – 50	Undiff. Tertiary		Alluvium: Red-brown, poorly-sorted, mixed clasts in a silty matrix		Airlift: 2.5L/s, EC: 7820uS/cm, pH: 8.21 Airlift: 3.0L/s, EC: 6840uS/cm, pH: 8.36 Airlift: 5.0L/s, EC: 6470uS/cm, pH: 8.36 Airlift: 0.7L/s, EC: 8370uS/cm, pH: 8.12	25-27.5m = bentonite seal	
50 – 51.5	CIDP		Pisolite: Dark-grey to yellow-brown, well-rounded, hard, magnetic with mixed clasts of chert and BIF	0 5000 10000 15000 20000 25000	Airlift: 0.7L/s, EC: 8390uS/cm, pH: 8.25 Airlift: 35.0L/s est, EC: 7740uS/cm, pH: 8.32	27.5-51.5m = gravel pack (3.2-6.4mm) 32.5-51.5m = 50mm CL18 PVC Slotted Casing (2mm slots) 51.5-53m = gravel pack (3.2-6.4mm)	

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COMPOSITE WELL LOG

Bore No: MDPZ7452C

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 07/12/2018
Completed: 08/12/2018
Drilled: Ausdrill NW
Logged By: TV

Method: DR / DTH
Fluid: Air
Bit Record: 0-28m = 241mm
28-32m = 191mm

Area: Mulga Downs
Elevation: 401 mAHD
Easting: 651346
Northing: 7545807
Projection: MGA94 Zone 50

Static Water Level: 4.29 mbgl **Date:** 10/12/2018

Remarks: Stick up: 0.60m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0	Upper Calcrete		Silcrete: Light-grey to light-brown, friable, vuggy, crystalline	0 – 25,000	Adjacent to MDPB0015	0-3.5 = cement/bentonite grout	
10			Calcrete: Brown and light-grey, minor silcrete layers, vuggy. Reacts strongly to acid		FWS @ 8m, Injecting Airlift: 0.2L/s, Injecting	0-8m = 50mm CL18 PVC Blank Casing	
20					Airlift: 0.5L/s, Injecting	3.5-5m = bentonite seal	
30			Calcrete: Smaller grain-size possibly due to change in drill-method		Airlift: 2.4L/s, EC: 8310uS/cm, pH: 8.44	5-32m = gravel pack (3.2-6.4mm)	
40					Airlift: 7.0L/s, EC: 7440uS/cm, pH: 8.23	8-32m = 50mm CL18 PVC Slotted Casing (2mm slots)	
50				0, 5000, 10000, 15000, 20000, 25000			
60							
70							
80							
90							
100							

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COMPOSITE WELL LOG

Bore No: MDPZ7453A

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 9/12/2018
Completed: 11/12/2018
Drilled: Ausdrill NW
Logged By: TV

Method: DR / DTH
Fluid: Air
Bit Record: 0-64m = 241mm
64-72.5 = 191mm

Area: Mulga Downs
Elevation: 404 mAHD
Easting: 651185
Northing: 7549447
Projection: MGA94 Zone 50

Static Water Level: 6.38 mbtoc
Date: 08/09/2019
Remarks: Stick up: 0.47m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion Diagram	Well Completion Notes
0 – 17	Upper Calcrete		Calcrete: White, light-grey and pink, vuggy, crystalline. Reacts strongly to acid		FWS @ 7m, Airlift: 0.2L/s, EC: 5800uS/cm, pH: 8.25		
17 – 20	Undiff. Tertiary		Gravel: Red-brown and black, vuggy, friable, manganiferous		Airlift: 0.5L/s, EC: 18230uS/cm, pH: 7.82, Red/Brown, Muddy		
20 – 30	Undiff. Tertiary		Silty Gravel: Brown, grey and white, very poorly sorted, mixed clasts of chert and shale in a silty matrix		Airlift: 3.3L/s, EC: 19520uS/cm, pH: 8.01	0-48m = cement/bentonite grout 0-52.5 = 50mm CL18 PVC	
30 – 50	CID/Pisolite		Pisolite: Red-brown, hard, strongly-magnetic pisolites. Minor clasts of subrounded chert and friable CID		Airlift: 2.5L/s, EC: 16860uS/cm, pH: 8.05, Light Brown Airlift: 1.4L/s, EC: 16000uS/cm, pH: 8.07, Red/Brown Airlift: 8.0L/s est, EC: 16880uS/cm, pH: 7.89 Airlift: 10.0L/s est, EC: 16630uS/cm, pH: 7.95, Clear		
50 – 52	CID/Pisolite		Clayey Gravel: Red- and yellow-brown, coarse alluvials - mainly chert		Airlift: 16.0L/s est, EC: 16470uS/cm, pH: 7.91, Light Brown	48-49.5m = bentonite seal	
52 – 70	Basal Calcrete		Calcrete: White, moderately-weathered, brecciated. Strong, brown colour alteration along fracture planes. Reacts strongly to acid		Airlift: 16.0L/s est, EC: 16900uS/cm, pH: 7.92, Cloudy Airlift: 16.0L/s est, EC: 17300uS/cm, pH: 8.09, Pink Airlift: 22.0L/s, EC: 15500uS/cm, pH: 7.86	49.5-64m = gravel pack (3.2-6.4mm) 52.5-72.5 = 50mm CL18 PVC	
70 – 72	Basal Calcrete		Calcrete: White, hard with high (40%) clay fraction - possible fracture zone		Airlift: 25.0L/s, EC: 18960uS/cm, pH: 7.61, Slightly Cloudy	64-72.5m = gravel pack (3.2-6.4mm)	

EC (µS/cm) scale: 0, 5000, 10000, 15000, 20000, 25000

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COMPOSITE WELL LOG

Bore No: MDPZ7453B

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 11/12/2018
Completed: 12/12/2018
Drilled: Ausdrill NW
Logged By: TV

Method: DR / DTH
Fluid: Air
Bit Record: 0-46m = 241mm
46-48 = 191mm

Area: Mulga Downs
Elevation: 400 mAHD
Easting: 651194
Northing: 7549450
Projection: MGA94 Zone 50

Static Water Level: 6.24 mbtoc **Date:** 08/09/2019

Remarks: Stick up: 0.49m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion Diagram	Well Completion Notes
0	Upper Calcrete		Calcrete: White, light-grey and pink, vuggy. Reacts strongly to acid	0 – 25,000	FWS @ 8m, Airlift: <0.1L/s est, Red/Brown, Muddy	0-23.5m = cement/bentonite grout	
10						0-30m = 50mm CL18 PVC	
20	Undiff. Tertiary		Gravel: Red-brown to black, friable, soft, manganiferous		Airlift: <0.1L/s est, Red/Brown, Muddy		
			Silty Gravel: Light-brown to grey, very poorly sorted, coarse clasts of chert, shale and dolomite in a silty matrix		Airlift: <0.1L/s est, Red/Brown, Muddy	23.5-24.5m = bentonite seal	
30	CID/Pisolite		CID: Red-brown, very friable, soft, "low-grade"		Airlift: 2.7L/s est, EC: 15240uS/cm, pH: 8.07, Light Brown		
			Pisolite: Red-brown, hard, magnetic, well-rounded. Minor, angular, coarse clasts mainly of chert		Airlift: 12.0L/s est, EC: 15980uS/cm, pH: 8.08, Light Brown	24.5-46m = gravel pack (3.2-6.4mm)	
40					Airlift: 17.0L/s est, EC: 17770uS/cm, pH: 8.01, Cloudy	30-48m = 50mm CL18 PVC	
50				0 5000 10000 15000 20000 25000	Airlift: 22.0L/s est, EC: 17530uS/cm, pH: 8.07, Cloudy	46-48m = gravel pack (3.2-6.4mm)	
60					48m: Airlift: 22.0L/s est, EC: 17140uS/cm, pH: 8.03		
70							
80							
90							
100							

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COMPOSITE WELL LOG

Bore No: MDPZ7453C

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 12/12/2018
Completed: 13/12/2018
Drilled: Ausdrill NW
Logged By: TV

Method: DR
Fluid: Air
Bit Record: 0-17m = 241mm

Area: Mulga Downs
Elevation: 400 mAHD
Easting: 651202
Northing: 7549450
Projection: MGA94 Zone 50

Static Water Level: 6.13 mbtoc **Date:** 08/09/2019

Remarks: Stick up: 0.49m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0	Upper Calcrete		Sand: Red-brown to pink, pisoloitic sand and vuggy calcrete	0 – 25,000	Airlift: 1.1L/s est, EC: 17400uS/cm, pH: 7.81, Light Red/Brown	0-5.5 = cement/bentonite grout	
10			Calcrete: Light-grey to pale-pink, friable, vuggy. Reacts strongly to acid			0-9m = 50mm CL18 PVC	
20			Calcrete: Pink and brown, vuggy and massive. Reacts strongly to acid		Airlift: 5.0L/s est, EC: 16260uS/cm, pH: 7.97, Cloudy	5.5-6m = bentonite seal	
30						6-17m = gravel pack (3.2-6.4mm)	
40						9-17m = 50mm CL18 PVC	
50							
60							
70							
80							
90							
100							

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COMPOSITE WELL LOG

Bore No: MDPZ7454

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 28/01/2019
Completed: 29/01/2019
Drilled: Ausdrill NW
Logged By: JJ

Method: DR / DTH
Fluid: Air
Bit Record: 0-4m = 241mm
4-58m = 191mm

Area: Mulga Downs
Elevation: 435 mAHD
Easting: 657062
Northing: 7555467
Projection: MGA94 Zone 50

Static Water Level: 26.62 mbtoc **Date:** 6/02/2019

Remarks: Stick up: 0.57m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Gamma Log	Field Notes	Well Completion Diagram	Well Completion Notes
0	Marra Mamba		Chert: Red stained, grey chert	0 – 30,000	0 – 200	Airlift: 0.1L/s est, Too muddy to sample	0-12m = Backfill 50mm CL18 PVC	
10			Chert: White to light purple, soft, highly weathered			Airlift: 0.1L/s est, Too muddy to sample	12-14m = bentonite seal	
20			Siltstone: Red stained, grey chert Clay: Puggy, pink to light brown			Airlift: <0.1L/s est, Too muddy to sample		
30			Shale: Creamy brown to light purple Chert: Grey, solid			Airlift: 0.15L/s est, Too muddy to sample		
40	Jerinah		Shale: Black shales with some quartz veins and pyrite between 50-58m	0, 6250, 12500, 18750, 25000	0, 50, 100, 150, 200	Airlift: <0.1L/s est, Too muddy to sample	14-58m = gravel pack (3.2-6.4mm) 50mm CL18 PVC	
50						Airlift: <0.1L/s est, Too muddy to sample		
60						Airlift: 0.15L/s, Too muddy to sample		
70						Airlift: 0.3L/s est, Black		
80								
90								
100								

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COMPOSITE WELL LOG

Bore No: MDPZ7455

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 31/01/2019
Completed: 1/02/2019
Drilled: Ausdrill NW
Logged By: AS

Method: DR / DTH
Fluid: Air
Bit Record: 0-4m = 241mm
4-61.5 = 191mm

Area: Mulga Downs
Elevation: 471 mAHD
Easting: 661114
Northing: 7554695
Projection: MGA94 Zone 50

Static Water Level: 31.50 mbtoc **Date:** 6/02/2019

Remarks: Stick up: 0.59m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Gamma Log	Field Notes	Well Completion Diagram	Well Completion Notes
0	Marra Mamba		Chert: red/brown coated chert	0 – 30,000	0 – 200			0-10m = cement
10			Chert: Black/brown chert with red staining					50mm CL18 PVC
			Clay: Red/white puggy clay					10-12m = bentonite seal
20			Clay: White puggy clay, becoming more yellow from 23m			FWS @ 13m, Airlift: 0.01L/s est		
			Clay: Light grey, puggy clay			Airlift: 0.01L/s est, Muddy		
30	Jerinah		Shale: Black, soft and friable shales	0, 6250, 12500, 18750, 25000	0, 50, 100, 150, 200	Airlift: 0.01L/s est, Black at 25m		
						Airlift: 0.01L/s est, Black		12-60m = gravel pack (3.2-6.4mm)
40						Airlift: 0.01L/s est, Black		50mm CL18 PVC
						Airlift: 0.1L/s est, Black		
50						Airlift: 1.0L/s, Black		
						Airlift: 1.3L/s, EC: 920µS/cm, pH: 6.65, Black		
60								
70								
80								
90								
100								

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COMPOSITE WELL LOG

Bore No: MDPZ7456A

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 5/02/2019
Completed: 8/02/2019
Drilled: Ausdrill NW
Logged By: AS

Method: DR / DTH
Fluid: Air
Bit Record: 0-52m = 241mm
52-120m = 191mm

Area: Mulga Downs
Elevation: 412 mAHD
Easting: 665851
Northing: 7547907
Projection: MGA94 Zone 50

Static Water Level: 8.12 mbtoc **Date:** 11/02/2019

Remarks: Stick up: 0.49m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Gamma Log	Field Notes	Well Completion Diagram	Well Completion Notes
0	Undiff. Tertiary		Gravelly Clay: Predominantly chert (minor ferrugionous) lithics in a red silty/clayey matrix.	0 – 25,000	0 – 200	Airlift: 15L/s, EC: 3420µS/cm, pH: 8.25	0-56m = cement/bentonite grout 50mm CL18 PVC	
10			Gravelly Clay: Chert lithics in a brown silty/clayey matrix. Increasing in iron content from 26m.			Airlift: 20L/s est, EC: 3210µS/cm, pH: 8.24		
20						Airlift: 20L/s est, EC: 3190µS/cm, pH: 8.26		
30	CID/Pisolite		CID: Dark brown-black, massive, fine grained. Red clay band from 39-40m.			Airlift: 20L/s est, EC: 3250µS/cm, pH: 8.33		
40			Clay: Brown-yellow, highly weathered BIF.			Airlift: 20L/s est, EC: 3240µS/cm, pH: 8.24		
50	Marra Mamba		BIF: Dark grey, very fine grained. Iron rich wih light brown highly weathered zones.			Airlift: 20L/s est, EC: 3200µS/cm, pH: 8.25		
60			Shale: Brown, highly weathered shale with dark brown weathered dolomite.			Airlift: 20L/s est, EC: 3190µS/cm, pH: 8.26	56-60m = bentonite seal	
70			Dolomite: Light grey dolomite with weathered brown shale.			Airlift: 20L/s est, EC: 3210µS/cm, pH: 8.23		
80			BIF: Pale grey, strongly magnetic (although soft and friable)			Airlift: 20L/s est, EC: 3150µS/cm, pH: 8.34		
90			Shale: Dark grey/black shale with minor light grey dolomite.			Airlift: 20L/s est, EC: 3230µS/cm, pH: 8.36	60-120.5m = gravel pack (3.2-6.4mm) 50mm CL18 PVC	
100						Airlift: 20L/s est, EC: 3220µS/cm, pH: 8.42		
110			Dolomite: Light grey dolomite with minor black shale.					
120			Shale: Dark grey/black shale with minor light grey dolomite.					
130								

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COMPOSITE WELL LOG

Bore No: MDPZ7456B

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 1/02/2019
Completed: 3/02/2019
Drilled: Ausdrill NW
Logged By: AS

Method: DR / DTH
Fluid: Air
Bit Record: 0-52m = 241mm
52-62 = 191mm

Area: Mulga Downs
Elevation: 412 mAHD
Easting: 665867
Northing: 7547918
Projection: MGA94 Zone 50

Static Water Level: 8.27 mbtoc **Date:** 11/02/2019

Remarks: Stick up: 0.55m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0 – 30	Undiff. Tertiary		Gravelly Clay: Predominantly chert (minor ferrugionous) lithics in a red silty/clayey matrix.	0 – 25000	No yield	0-42m = cement; 0-46m = 50mm CL18 PVC	
			Gravelly Clay: Chert lithics in a brown silty/clayey matrix. Increasing in iron content from 26m.		Muddy; Airlift: 1.2L/s, EC: 2330µS/cm, pH: 7.67; Airlift: 0.8L/s, EC: 2220µS/cm, pH: 7.85; Airlift: 0.2L/s, Muddy		
30 – 40	CID/Pisolite		CID: Dark brown-black, massive, fine grained. Red clay band from 39-40m.		Airlift: 2.0L/s, EC: 3280µS/cm, pH: 8.05		
40 – 60	Marra Mamba		Clay: Brown-yellow, highly weathered BIF.		Airlift: 0.1L/s, Strong inflows from 35-39m (8-10 L/s)	42-44m = bentonite seal	
			BIF: Dark grey, very fine grained. Iron rich wih light brown highly weathered zones.	0 5000 10000 15000 20000 25000	Airlift: 6.5L/s, EC: 3260µS/cm, pH: 8.45, Low yields from 43-45m; Airlift: 1.5L/s, EC: 3230µS/cm, pH: 8.3; Airlift: 5.0L/s, EC: 3210µS/cm, pH: 8.34	44-52m = gravel pack (3.2-6.4mm); 46 - 62m = 50mm CL18 PVC; 52-62m = gravel pack (3.2-6.4mm)	

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COMPOSITE WELL LOG

Bore No: MDPZ7456C

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

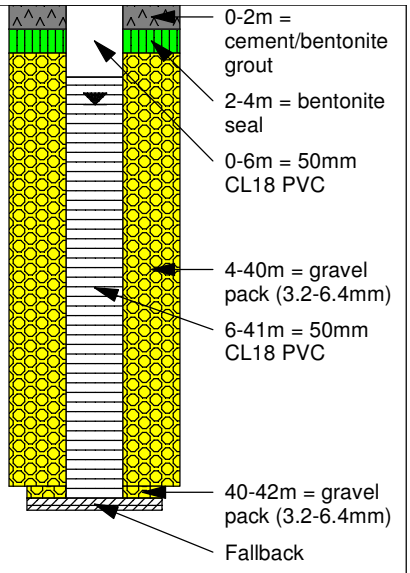
Commenced: 3/02/2019
Completed: 4/02/2019
Drilled: Ausdrill NW
Logged By: AS

Method: DR / DTH
Fluid: Air
Bit Record: 0-40m = 241mm
40-42m = 191mm

Area: Mulga Downs
Elevation: 412 mAHD
Easting: 665858
Northing: 7547913
Projection: MGA94 Zone 50

Static Water Level: 8.28 mbtoc **Date:** 11/02/2019

Remarks: Stick up: 0.53m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion Diagram	Well Completion Notes
0 – 130	Undiff. Tertiary (0–30m); CID/Pisolite (30–42m)		Gravelly Clay: Predominantly chert (minor ferrugionous) lithics in a red silty/clayey matrix. (0–2m) Gravelly Clay: Chert lithics in a brown silty/clayey matrix. Increasing in iron content from 26m. (2–30m) CID: Dark brown-black, massive, fine grained. Red clay band from 39-40m. (30–42m)	0 – 25,000	Above water table Very low yield- muddy sample Airlift: 1.5L/s, EC: 2640µS/cm, pH: 8.35 Airlift: 3.0L/s, EC: 2610µS/cm, pH: 8.31 Airlift: 1.0L/s, EC: 2520µS/cm, pH: 8.12 Airlift: 10.0L/s, EC: 3210µS/cm, pH: 8.14 Airlift: 0.1L/s, Low yields through clay band		0-2m = cement/bentonite grout 2-4m = bentonite seal 0-6m = 50mm CL18 PVC 4-40m = gravel pack (3.2-6.4mm) 6-41m = 50mm CL18 PVC 40-42m = gravel pack (3.2-6.4mm) Fallback

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COMPOSITE WELL LOG

Bore No: MDPZ7457A

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 9/02/2019
Completed: 11/02/2019
Drilled: Ausdrill NW
Logged By: TV

Method: DR / DTH
Fluid: Air
Bit Record: 0-70m = 241mm
70-100m = 191mm

Area: Mulga Downs
Elevation: 404 mAHD
Easting: 656907
Northing: 7548169
Projection: MGA94 Zone 50

Static Water Level: 4.71 mbtoc **Date:** 27/02/2019

Remarks: Stick up: 0.55m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion Diagram	Well Completion Notes
0–110	Upper Calcrete / CID/Pisolite / Basal Calcr / Marra Mamba		Calcrete: White, chalky, friable, vuggy. Strongly weathered, reacts strongly to acid Calcrete: Calcrete/Quartz, white/milky, vuggy, angular. Strong WBZ Calcrete: Calcrete/Silcrete, light-brown, subangular, vuggy, porous. Reacts variably to acid Pisolite: Pisolites/CID, red-brown, small, round, magnetic pisolites with subangular fragments of CID ore CID: Dark-grey to brown, angular, vuggy. Limonite and goethite staining Calcrete: White, hard, strong reaction to acid Clay: Basal Detrital Clay (BCL), soft, friable, massive Laterite: Hydrated hardcap, dark-grey to brown, vitreous, vuggy, "clinker-like", non-magnetic, goethitic and limonitic Chert: Chert/BIF, weathered MM: Grey and yellow, well-bedded, limonitic Chert: Chert/Shale/BIF, dark-grey and brown, strongly-bedded, fresh, subangular	0 – 25,000	Adjacent to MDPB0014 Injecting, white FWS @ 13m, brown Airlift: 3.4L/s, EC: 5470µS/cm, pH: 7.95, Yellow-brown Airlift: 8.5L/s, EC: 5740µS/cm, pH: 8.43, Brown Airlift: 12.0L/s, Light brown Airlift: 7.0L/s, EC: 6670µS/cm, pH: 8.43, Brown Airlift: 8.5L/s, EC: 11280µS/cm, pH: 8.44, Red-brown Airlift: 4.0L/s est, EC: 11080µS/cm, pH: 8.49, Red-brown Airlift: 4.0L/s est, EC: 13000µS/cm, pH: 8.28, Light grey Airlift: 5.0L/s est, EC: 12990µS/cm, pH: 8.3, Light grey Airlift: <1.0L/s est, EC: 13460µS/cm, pH: 8.3, Dark brown Airlift: 6.0L/s est, EC: 13480µS/cm, pH: 8.35, Dark brown Airlift: 10.0L/s est, EC: 14220µS/cm, pH: 8.21, Dark grey Airlift: 14.0L/s est, EC: 14600µS/cm, pH: 8.12, Light grey Airlift: 16.0L/s est, EC: 15030µS/cm, pH: 8.25, Light brown Airlift: 20.0L/s est, EC: 15350µS/cm, pH: 8.24, Very light brown	0-61m = cement/bentonite grout 0-76m = 50mm CL18 PVC 60.5-66m = bentonite seal 66-70m = gravel pack (3.2-6.4mm) 70-100m = gravel pack (3.2-6.4mm) 76-100m = 50mm CL18 PVC	

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COMPOSITE WELL LOG

Bore No: MDPZ7457B

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 11/02/2019
Completed: 12/02/2019
Drilled: Ausdrill NW
Logged By: TV

Method: DR
Fluid: Air
Bit Record: 0-59m = 241mm

Area: Mulga Downs
Elevation: 404 mAHD
Easting: 656917
Northing: 7548168
Projection: MGA94 Zone 50

Static Water Level: 4.64 mbtoc
Date: 27/02/2019
Remarks: Stick up: 0.54m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion Diagram	Well Completion Notes
0	Upper Calcrete		Calcrete: White to pink, hard, strong reaction to acid	0 – 25,000	Adjacent to MDPB0014		
10			Quartz Vein: White, milky and smoky,		Injecting, white		
20			Calcrete: Calcrete/Silcrete, light-brown and pink, strong reaction to acid		Airlift: 4.3L/s, EC: 5750µS/cm, pH: 8.44, Light brown		0-33.8m = cement/bentonite grout
			Quartz Vein: White, milky and smoky,		Airlift: 6.3L/s, EC: 5630µS/cm, pH: 8.32, Pink-brown		0-41m = 50mm CL18 PVC
30			Calcrete: Light-brown, friable, vuggy, containing subrounded grains of chert and quartz. Strong reaction to acid		Airlift: 7.1L/s, EC: 5920µS/cm, pH: 8.37, Light pink-brown		
40	CID/Pisolite		Pisolite: Red-brown, hard, round, strongly-magnetic		Airlift: 10.0L/s est, EC: 6330µS/cm, pH: 8.35, Red-brown		33.8-35m = bentonite seal
					Airlift: 15.0L/s est, EC: 9510µS/cm, pH: 8.05, Red-brown		
50			CID: Dark-grey, weakly magnetic, vitreous. Probably ore-grade	0 5000 10000 15000 20000 25000	Airlift: 15.0L/s est, EC: 11550µS/cm, pH: 8.13, Red-brown		35-59m = gravel pack (3.2-6.4mm)
	Basal Calcrete		Calcrete: Calcrete/CID, white and dark-grey, rubbly, broken. Strong reaction to acid. Difficult to drill, collapsing around hammer		Injecting, very low flow		41-59m = 50mm CL18 PVC
60					Airlift: 12.0L/s est, EC: 12060µS/cm, pH: 8.13		
70							
80							
90							
100				0 5000 10000 15000 20000 25000			
110							

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COMPOSITE WELL LOG

Bore No: MDPZ7457C

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 12/02/2019
Completed: 13/02/2019
Drilled: Ausdrill NW
Logged By: TV

Method: DR
Fluid: Air
Bit Record: 0-35m = 241mm

Area: Mulga Downs
Elevation: 404 mAHD
Easting: 656927
Northing: 7548166
Projection: MGA94 Zone 50

Static Water Level: 4.67 mbtoc **Date:** 27/02/2019

Remarks: Stick up: 0.57m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion Diagram	Well Completion Notes
0	Upper Calcrete		Calcrete: White, light-brown and pink, crystalline with round quartz inclusions. Strong reaction to acid	0 – 25,000	Adjacent to MDPB0014	0-8.5m = cement/bentonite grout 8.5-10m = bentonite seal 0-19m = 50mm CL18 PVC 10-35m = gravel pack (3.2-6.4mm) 19-35m = 50mm CL18 PVC	
10			Quartz Vein: Quartz Vein/Calcrete, white to light-brown, water-bearing		Injecting, white		
20			Calcrete: Brown and white, crystalline, friable. Reacts strongly to acid		Airlift: 3.7L/s, EC: 5780µS/cm, pH: 8.29, Light-brown		
30			Calcrete: Dark-brown, friable. Reacts strongly to acid		Airlift: 4.1L/s, EC: 7140µS/cm, pH: 8.28, Light-brown/pink		
40					Airlift: 7.0L/s est, EC: 6260µS/cm, pH: 8.27, Light-brown/pink		
50					Airlift: 14.0L/s est, EC: 6450µS/cm, pH: 8.22, Light-pink/dark-brown		
60							
70							
80							
90							
100							
110							

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COMPOSITE WELL LOG

Bore No: MDPZ7458A

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

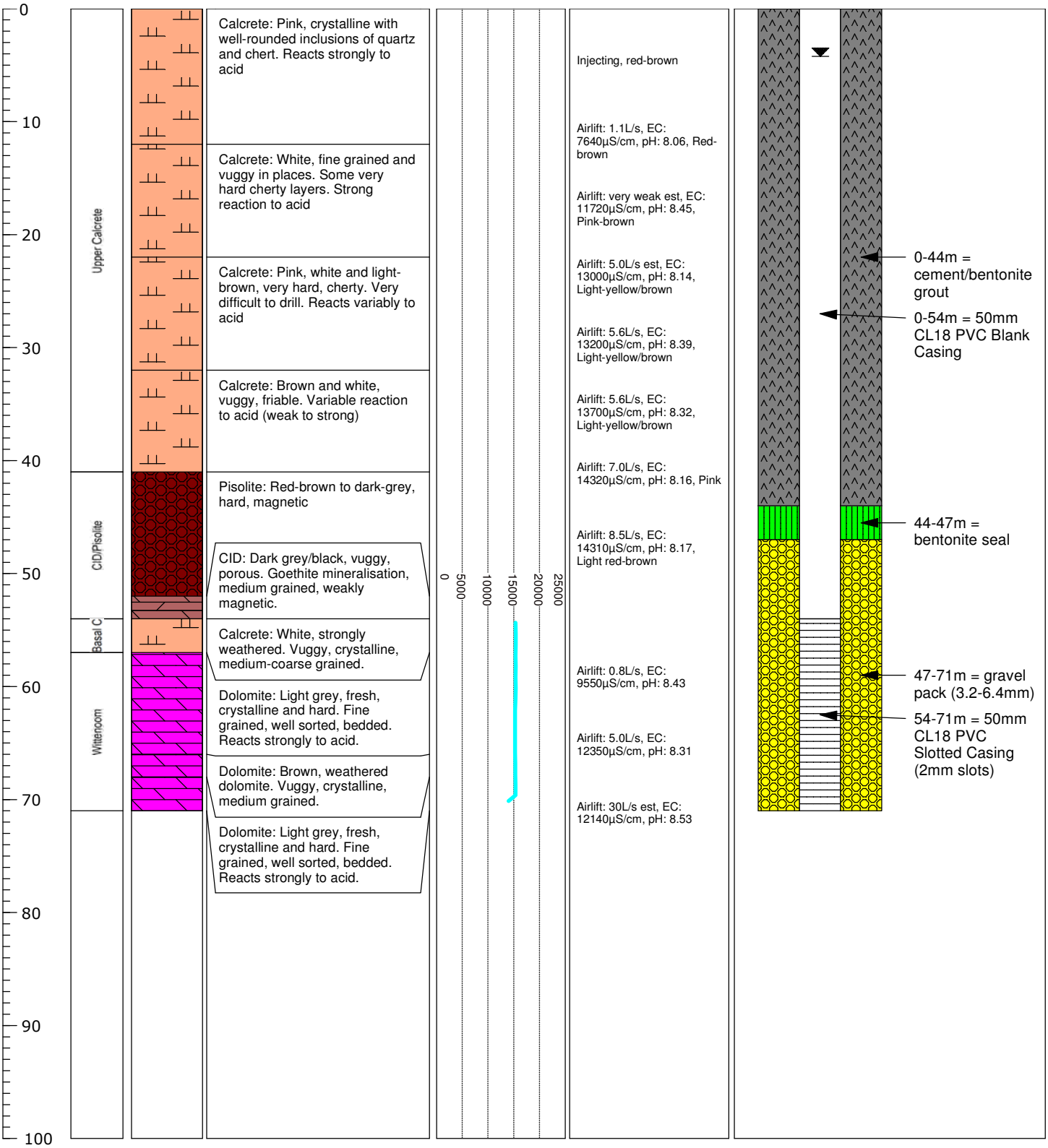
Commenced: 15/02/2019
Completed: 18/02/2019
Drilled: Ausdrill NW
Logged By: ATS

Method: DR
Fluid: Air
Bit Record: 0-71m = 241mm

Area: Mulga Downs
Elevation: 399 mAHD
Easting: 656652
Northing: 7546148
Projection: MGA94 Zone 50

Static Water Level: 4.23 mbtoc
Date: 27/02/2019
Remarks: Stick up: 0.58m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0 – 40	Upper Calcrete		Calcrete: Pink, crystalline with well-rounded inclusions of quartz and chert. Reacts strongly to acid	0 – 25,000	Injecting, red-brown		
10 – 20	Upper Calcrete		Calcrete: White, fine grained and vuggy in places. Some very hard cherty layers. Strong reaction to acid		Airlift: 1.1L/s, EC: 7640µS/cm, pH: 8.06, Red-brown		
20 – 30	Upper Calcrete		Calcrete: Pink, white and light-brown, very hard, cherty. Very difficult to drill. Reacts variably to acid		Airlift: very weak est, EC: 11720µS/cm, pH: 8.45, Pink-brown		
30 – 40	Upper Calcrete		Calcrete: Brown and white, vuggy, friable. Variable reaction to acid (weak to strong)		Airlift: 5.0L/s est, EC: 13000µS/cm, pH: 8.14, Light-yellow/brown		
40 – 50	CID/Pisolite		Pisolite: Red-brown to dark-grey, hard, magnetic		Airlift: 5.6L/s, EC: 13200µS/cm, pH: 8.39, Light-yellow/brown		
50 – 52	CID/Pisolite		CID: Dark grey/black, vuggy, porous. Goethite mineralisation, medium grained, weakly magnetic.		Airlift: 5.6L/s, EC: 13700µS/cm, pH: 8.32, Light-yellow/brown		
52 – 54	Basal C		Calcrete: White, strongly weathered. Vuggy, crystalline, medium-coarse grained.		Airlift: 7.0L/s, EC: 14320µS/cm, pH: 8.16, Pink		
54 – 60	Wittenoom		Dolomite: Light grey, fresh, crystalline and hard. Fine grained, well sorted, bedded. Reacts strongly to acid.		Airlift: 8.5L/s, EC: 14310µS/cm, pH: 8.17, Light red-brown		
60 – 70	Wittenoom		Dolomite: Brown, weathered dolomite. Vuggy, crystalline, medium grained.		Airlift: 0.8L/s, EC: 9550µS/cm, pH: 8.43		
70 – 100	Wittenoom		Dolomite: Light grey, fresh, crystalline and hard. Fine grained, well sorted, bedded. Reacts strongly to acid.		Airlift: 5.0L/s, EC: 12350µS/cm, pH: 8.31		
					Airlift: 30L/s est, EC: 12140µS/cm, pH: 8.53		



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COMPOSITE WELL LOG

Bore No: MDPZ7458B

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 18/02/2019
Completed: 20/02/2019
Drilled: Ausdrill NW
Logged By: ATS

Method: DR
Fluid: Air
Bit Record: 0-52m = 241mm

Area: Mulga Downs
Elevation: 399 mAHD
Easting: 656656
Northing: 7546145
Projection: MGA94 Zone 50

Static Water Level: 4.29 mbtoc
Date: 27/02/2019
Remarks: Stick up: 0.56m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0 – 40	Upper Calcrete		Calcrete: Pink, crystalline with well-rounded inclusions of quartz and chert. Reacts strongly to acid	0 – 25,000	Above water table	0-41m = cement/bentonite grout; 0-45m = 50mm CL18 PVC	
10 – 30	Upper Calcrete		Calcrete: White, fine grained and vuggy in places. Some very hard cherty layers. Strong reaction to acid		Airlift: 0.4L/s, EC: 12390µS/cm, pH: 8.57; Airlift: 7.0L/s est, EC: 12620µS/cm, pH: 8.32, First increase in yield @ 13m		
20 – 30	Upper Calcrete		Calcrete: Pink, white and light-brown, very hard, cherty. Very difficult to drill. Reacts variably to acid		Airlift: 13.0L/s est, EC: 12810µS/cm, pH: 8.31; Airlift: 10.0L/s est, EC: 13150µS/cm, pH: 8.39		
30 – 40	Upper Calcrete		Calcrete: Brown and white, vuggy, friable. Variable reaction to acid (weak to strong)		Airlift: 12.0L/s est, EC: 13250µS/cm, pH: 8.29; Airlift: 20.0L/s est, EC: 14150µS/cm, pH: 8.40		
40 – 50	CID/Pisolite		Pisolite: Red-brown to dark-grey, hard, magnetic	0, 5000, 10000, 15000, 20000, 25000	Airlift: 20.0L/s est, EC: 14250µS/cm, pH: 8.28; Airlift: 10.5L/s est, EC: 13530µS/cm, pH: 8.25	41-43m = bentonite seal; 43-52m = gravel pack (3.2-6.4mm); 45-52m = 50mm CL18 PVC	
50 – 100							

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COMPOSITE WELL LOG

Bore No: MDPZ7458C

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 20/02/2019
Completed: 25/02/2019
Drilled: Ausdrill NW
Logged By:

Method: DR
Fluid: Air
Bit Record: 0-41m = 241mm

Area: Mulga Downs
Elevation: 399 mAHD
Easting: 656667
Northing: 7546146
Projection: MGA94 Zone 50

Static Water Level: 4.36 mbtoc **Date:** 27/02/2019

Remarks: Stick up: 0.63m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0 – 40	Upper Calcrete		Calcrete: Pink, crystalline with well-rounded inclusions of quartz and chert. Reacts strongly to acid	0 – 25,000	Above water table, Injecting	0-1m = cement/bentonite grout 1-3m = bentonite seal 0-5m = 50mm CL18 PVC 3-41m = gravel pack (3.2-6.4mm) 5-41m = 50mm CL18 PVC	
10 – 20			Calcrete: White, fine grained and vuggy in places. Some very hard cherty layers. Strong reaction to acid		Airlift: 0.8L/s, EC: 12350µS/cm, pH: 8.11 Airlift: 8.0L/s, EC: 12050µS/cm, pH: 8.42		
20 – 30			Calcrete: Pink, white and light-brown, very hard, cherty. Very difficult to drill. Reacts variably to acid		Airlift: 12.0L/s, EC: 12610µS/cm, pH: 8.33 Airlift: 9.0L/s, EC: 12410µS/cm, pH: 8.35		
30 – 40			Calcrete: Brown and white, vuggy, friable. Variable reaction to acid (weak to strong)		Airlift: 20.0L/s, EC: 12670µS/cm, pH: 8.38 Airlift: 15.0L/s, EC: 13150µS/cm, pH: 8.32		
40 – 100				0, 5000, 10000, 15000, 20000, 25000			

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COMPOSITE WELL LOG

Bore No: MDPZ7459

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 26/02/2019
Completed: 27/02/2019
Drilled: Ausdrill NW
Logged By: ATS

Method: DR
Fluid: Air
Bit Record: 0-28m = 241mm

Area: Mulga Downs
Elevation: 407 mAHD
Easting: 650263
Northing: 7554484
Projection: MGA94 Zone 50

Static Water Level: 11.15 mbtoc **Date:** 2/03/2019

Remarks: Stick up: 0.54m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0	Alluvium		Clay: Red/brown silty clay with clasts of BIF, Chert and minor quartz (0.5-15mm). Subrounded, poorly sorted, fine-coarse grained.	0 – 25,000	Above water table, Injecting	0-1m = cement/bentonite grout 1-3m = bentonite seal 0-5m = 50mm CL18 PVC 3-28m = gravel pack (3.2-6.4mm) 5-28m = 50mm CL18 PVC	
10			Silty Gravel: Clasts of BIF, chert and quartz with minor red/brown silty clay. (2-30mm). Subangular, poorly sorted, fine-coarse grained.		Airlift: 0.01L/s est, EC: 1894µS/cm, pH: 8.51, Muddy		
20	Undiff. Tertiary		Clay: Red/brown silty clay with clasts of BIF and Chert (0.5-10mm). Subrounded/Subangular, poorly sorted, fine-coarse grained.		Airlift: 1.0L/s, EC: 1622µS/cm, pH: 8.34		
30			Clayey Gravel: Clasts of BIF, chert and dolomite with minor silty clay. (0.5-5mm). Subangular, poorly sorted, fine-coarse grained.		Airlift: 3.5L/s, EC: 473µS/cm, pH: 8.96, Yield increase @ 20m		
40			Clay: Red/brown puggy clay		Airlift: 0.01L/s est, Muddy		
50				0, 5000, 10000, 15000, 20000, 25000			
60							
70							
80							
90							
100							

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COMPOSITE WELL LOG

Bore No: MDPZ7460A

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 28/02/19
Completed: 3/03/19
Drilled: Ausdrill NW
Logged By: TV

Method: DR(0-58m) / DTH(58-112m)
Fluid: Air
Bit Record: 0-58m = 241mm
58-112m = 191

Area: Mulga Downs
Elevation: 404 mAHD
Easting: 663202
Northing: 7547987
Projection: MGA94 Zone 50

Static Water Level: 4.85 mbtoc **Date:** 10/03/2019

Remarks: Stick up: 0.46m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Gamma Log	Field Notes	Well Completion Diagram	Well Completion Notes
0	Undiff. Tertiary		Silty Gravel: Alluvium/Gravel/Silt, mainly BIF and chert clasts in a silty matrix	0 – 25,000	0 – 200	Ajacent to MDPB0013 Injecting Airlift: 0.4L/s, EC: 2320µS/cm, pH: 8.08, Muddy	0-55m = cement/bentonite grout 50mm CL18 PVC	
20			Silty Gravel: Alluvium/Pisolites/Gravel/Silt, coarse gravels (BIF and Chert) with well-rounded, magnetic pisolites in a silty matrix			Airlift: 0.6L/s, EC: 2670µS/cm, pH: 7.87, Muddy Airlift: 5.0L/s, EC: 3530µS/cm, pH: 7.88 Airlift: 4.2L/s, EC: 3550µS/cm, pH: 8.01		
30			Gravelly Clay: Alluvium/Clay, soft, semi-plastic clay with minor subangular clasts of BIF and chert			Airlift: 0.01L/s est, Muddy		
40	CID/Pisolite		Pisolite: CID/Pisolites, friable, high-Fe CID and well-rounded (buckshot), magnetic pisolites			Airlift: 1.3L/s, EC: 3250µS/cm, pH: 8.10, Muddy Airlift: 2.5L/s, EC: 3570µS/cm, pH: 7.94		
50			Gravelly Clay: Alluvium/Clay, soft, friable clay with sub-angular, coarse-grained clasts of BIF			No yield		
60	Marra Mamba		Chert: Multicoloured, appears permeable, glassy, very hard to drill. Dolomitic in places, minor shale horizons			Airlift: 1.2L/s, EC: 2740µS/cm, pH: 8.18, Yellow/brown Airlift: 10.3L/s, EC: 4610µS/cm, pH: 8.23, Grey/brown Airlift: 12.2L/s, EC: 4720µS/cm, pH: 8.42, Light-grey/brown	55-59.6m = bentonite seal	
70						Airlift: 14.4L/s, EC: 4770µS/cm, pH: 8.49		
80			Shale: Finely bedded (laminated), with minor cherty layers and dolomitic intervals (esp. 102-104m). Brown staining on some fracture/cleavage planes			Airlift: 18L/s, EC: 4850µS/cm, pH: 8.32, Dark-grey Airlift: 20L/s est, EC: 5020µS/cm, pH: 8.45	59.6-112m = gravel pack (3.2-6.4mm) 50mm CL18 PVC	
90						Airlift: 20L/s est, EC: 5180µS/cm, pH: 8.32, Dark-grey		
100						Airlift: 25L/s est, EC: 5200µS/cm, pH: 8.46, Light-grey Airlift: 25L/s est, EC: 5340µS/cm, pH: 8.43, Light-grey		
110						Airlift: 25L/s est, EC: 5160µS/cm, pH: 8.49, Light-grey		
120								

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COMPOSITE WELL LOG

Bore No: MDPZ7460B

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 4/03/19
Completed: 5/03/19
Drilled: Ausdrill NW
Logged By: TV

Method: DR
Fluid: Air
Bit Record: 0-53.4m = 241mm

Area: Mulga Downs
Elevation: 404 mAHD
Easting: 663199
Northing: 7547984
Projection: MGA94 Zone 50

Static Water Level: 5.07 mbtoc
Date: 10/03/2019
Remarks: Stick up: 0.52m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion Diagram	Well Completion Notes
0	Undiff. Tertiary		Silty Gravel: Alluvium/Gravel/Silt, coarse-grained gravel (mainly chert with minor shale and BIF) in a fine, silty matrix.	0 2500	Adjacent to MDPB0013	0-35m = cement/bentonite grout	
10			Gravel: Alluvium/Pisolites/Gravel/Silt, round, hard, magnetic pisolites with angular-round clasts of chert, shale and BIF in a silty matrix		Mud, Injecting	0-45.4m = 50mm CL18 PVC Blank Casing	
20			Gravelly Silt: Alluvium/Silt, friable, possible CID		Airlift: 1.4L/s, EC: 3870µS/cm, pH: 8.42, Red-brown		
30			Gravel: Alluvium/Pisolites/Gravel/Silt, round, hard, magnetic pisolites with sub-rounded clasts of chert and shale in a silty matrix. Clasts are angular when fractured by drilling		Airlift: 1.9L/s, EC: 3860µS/cm, pH: 8.29, Red-brown Airlift: 1.8L/s, EC: 3520µS/cm, pH: 8.28, Red-brown	33.4-35m = bentonite seal	
40	CID/Pisolite		Pisolite: Alluvium/Pisolites/CID, well-rounded, hard, magnetic "buckshot" pisolites		Airlift: 2.7L/s, Red-brown	Collapsed Material	
50			Pisolite: Alluvium/Pisolites/Gravel, well-rounded, hard, magnetic pisolites with coarse, sub-round gravels (chert and shale)	0 5000 10000 15000 20000 25000	Airlift: 5.6L/s, EC: 4000µS/cm, pH: 7.81, Red-brown Airlift: 8.5L/s, Red-brown	40-42.3m = gravel pack (3.2-6.4mm) Collapsed Material	
60			Gravelly Clay: Alluvium/Clay, soft, friable clay with sub-angular, coarse-grained clasts of BIF		Airlift: 1.8L/s, EC: 1967µS/cm, pH: 8.01, Yellow	45.4-51.4m = 50mm CL18 PVC Slotted Casing (2mm slots) 51.4-53.4m = 50mm CL18 PVC Blank Casing	
70							
80							
90							
100				0 5000 10000 15000 20000 25000			
110							
120							

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COMPOSITE WELL LOG

Bore No: MDPZ7460C

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 5/03/19
Completed: 6/03/19
Drilled: Ausdrill NW
Logged By: TV

Method: DR
Fluid: Air
Bit Record: 0-29.3m = 241mm

Area: Mulga Downs
Elevation: 404 mAHD
Easting: 663192
Northing: 7547975
Projection: MGA94 Zone 50

Static Water Level: 5.23 mbtoc **Date:** 10/03/2019

Remarks: Stick up: 0.65m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion Diagram	Well Completion Notes
0	Undiff. Tertiary		Gravelly Silt: Alluvium/Gravel, multicoloured clasts of chert, shale and calcrete in a silty matrix	0 5000 10000 15000 20000 25000	Adjacent to MDPB0013	0-11m = cement/bentonite grout	
10			Gravelly Clay: Alluvium/Clay/Gravel, silty clay with clasts of chert and shale		Mud, Injecting, Pink/brown	0-17.3m = 50mm CL18 PVC Blank Casing	
20			Gravel: Alluvium/Gravel/Pisolites, angular clasts of chert and shale with rounded, hard, magnetic pisolites		Airlift: 1.4L/s, EC: 4150µS/cm, pH: 8.10, Light-red/brown	11-12m = bentonite seal	
30					Airlift: 3.4L/s, EC: 3540µS/cm, pH: 8.17, Light-red/brown	12-29.3m = gravel pack (3.2-6.4mm)	
40					Airlift: 3.7L/s, EC: 4080µS/cm, pH: 8.14, Light-red/brown	17.3-29.3m = 50mm CL18 PVC Slotted Casing (2mm slots)	
50							
60							
70							
80							
90							
100							
110							
120							

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COMPOSITE WELL LOG

Bore No: MDPZ7461

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 7/03/19
Completed: 9/03/19
Drilled: Ausdrill NW
Logged By: ATS

Method: DR(0-54m)/DTH(54-119.2m)
Fluid: Air
Bit Record: 0-54m = 241mm
54-119.2m = 191mm

Area: Mulga Downs
Elevation: 404 mAHD
Easting: 656010
Northing: 7542996
Projection: MGA94 Zone 50

Static Water Level: 4.88 mbtoc **Date:** 10/03/2019

Remarks: Stick up: 0.47m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion Diagram	Well Completion Notes
0–130	Upper Calcrete; CID/Pisolite; Wiltenoom		Calcrete: Red/brown - white calcrete, fine - medium grained. Calcrete: Brown calcrete matrix with goethitic clasts. Pisolite: Pisolite/CID, brown/red pisolite with consolidated massive CID mainly from 48-50m. Strongly magnetic. CID: Brown - black massive CID. Very hard, strongly magnetic. Chert: Dark brown - black bedded chert with calcite veining. Calcite content decreasing from 60m. Dolomite: Light grey, fresh, crystalline and hard. Fine grained, well sorted, bedded. Reacts strongly to acid.	0 – 25000	Injecting, Pink Airlift: 1.3L/s, EC: 4200µS/cm, pH: 8.11, Pink-white Airlift: 3.8L/s, EC: 4000µS/cm, pH: 8.27, Light-brown Airlift: 8.0L/s est, EC: 3880µS/cm, pH: 8.66, Light-brown Airlift: 8.0L/s est, EC: 4170µS/cm, pH: 8.38, Light-brown Airlift: 10.0L/s est, EC: 3480µS/cm, pH: 8.18, Light-brown Airlift: 10.0L/s est, EC: 3500µS/cm, pH: 8.35, Light-brown Airlift: 8.0L/s est, EC: 3990µS/cm, pH: 8.31, Clear Airlift: 6.0L/s est, EC: 5340µS/cm, pH: 8.39, Brown/yellow Airlift: 15.0L/s est, EC: 5360µS/cm, pH: 8.37, Dark-purple Airlift: 15.0L/s est, EC: 7150µS/cm, pH: 8.28, Dark-purple Airlift: 15.0L/s est, EC: 6520µS/cm, pH: 8.24, Brown/green Airlift: 15.0L/s est, EC: 7700µS/cm, pH: 8.28, Creamy white Airlift: 15.0L/s est, EC: 6870µS/cm, pH: 8.27, Creamy white Airlift: 15.0L/s est, EC: 6680µS/cm, pH: 8.25, Creamy white Airlift: 15.0L/s est, EC: 6560µS/cm, pH: 8.23, Creamy white Airlift: 15.0L/s est, EC: 7310µS/cm, pH: 8.24, Creamy white Airlift: 15.0L/s est, EC: 6250µS/cm, pH: 8.23, Creamy white Airlift: 15.0L/s est, EC: 6880µS/cm, pH: 8.24, Creamy white Airlift: 15.0L/s est, EC: 7410µS/cm, pH: 8.20, Creamy white	0-3m = bentonite seal 0-5.2m = 50mm CL18 PVC Blank Casing 3-119.2m = gravel pack (3.2-6.4mm) 5.2-119.2m = 50mm CL18 PVC Slotted Casing (2mm slots)	

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COMPOSITE WELL LOG

Bore No: MDPZ7462A

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 13/03/19
Completed: 17/03/19
Drilled: Ausdrill NW
Logged By:

Method: DR(0-58m)/DTH(54-120m)
Fluid: Air
Bit Record: 0-58m = 241mm
58-120m = 191mm

Area: Mulga Downs
Elevation: 405 mAHD
Easting: 644800
Northing: 7548089
Projection: MGA94 Zone 50

Static Water Level: 4.89 mbtoc **Date:** 18/04/2019

Remarks: Stick up: 0.58m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm) 0–25,000	Gamma Log 0–200	Field Notes	Well Completion: Diagram	Well Completion: Notes
0–10	Upper Calcrete		Clay: Top Soil, red/brown silty clay matrix (80%) with clasts of BIF and chert (20%). Subrounded, fine to coarse grained.			Above water table, Injecting		
10–30	Upper Calcrete		Calcrete: Light brown, medium grained calcrete. Soft and vuggy.			Airlift: 2.5L/s, EC: 3850µS/cm, pH: 8.16, Brown Airlift: 4.5L/s, EC: 3540µS/cm, pH: 8.26, Light-brown Airlift: 7.0L/s, EC: 3510µS/cm, pH: 8.29, Light-brown Airlift: 8.5L/s, EC: 3580µS/cm, pH: 8.27, Light-brown	0-59m = cement/bentonite grout 50mm CL18 PVC	
30–50	Undiff. Tertiary		Gravel: Brown-light pink carbonate matrix (reacts to acid) with assorted lithics of chert, BIF and quartz.			Airlift: 12.5L/s, EC: 3720µS/cm, pH: 8.30, Light-brown Airlift: 12.5L/s, EC: 4020µS/cm, pH: 8.28, Light-brown/creamy Airlift: 12.5L/s, EC: 3950µS/cm, pH: 8.45, Light-brown/creamy Airlift: 12.5L/s, EC: 4100µS/cm, pH: 8.41, Light-brown		
50–60	Undiff. Tertiary/Pisolite		Pisolite: Dark brown-black pisolites. Medium to coarse grained, rounded.					
60–70	Basal Calcrete/Pisolite		Silcrete: Creamy/beige, very hard silcrete with strong calcite veining.			Airlift: 4.0L/s, EC: 3940µS/cm, pH: 8.42 Airlift: 4.0L/s	59-61m = bentonite seal	
70–120	Witenoom		Dolomite: Light grey, fresh, crystalline and hard. Calcite content decreasing at 68m. Fine grained, well sorted, bedded. Reacts weakly to acid.			Airlift: 4.0L/s, EC: 3440µS/cm, pH: 8.71, Light-grey Airlift: 4.0L/s Airlift: 4.0L/s, EC: 3530µS/cm, pH: 8.77, Light-grey Airlift: 4.0L/s, EC: 3450µS/cm, pH: 8.64, Light-grey Airlift: 4.0L/s Airlift: 4.0L/s, EC: 3400µS/cm, pH: 8.69, Light-grey Airlift: 4.0L/s, EC: 3460µS/cm, pH: 8.78, Light-grey Airlift: 4.0L/s, EC: 3330µS/cm, pH: 8.73, Light-grey Airlift: 4.0L/s, EC: 3520µS/cm, pH: 8.71, Light-grey	61-120m = gravel pack (3.2-6.4mm) 50mm CL18 PVC	

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COMPOSITE WELL LOG

Bore No: MDPZ7462B

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 19/03/19
Completed: 21/03/19
Drilled: Ausdrill NW
Logged By: TV

Method: DR
Fluid: Air
Bit Record: 0-58.5m = 241mm

Area: Mulga Downs
Elevation: 405 mAHD
Easting: 644800
Northing: 7548101
Projection: MGA94 Zone 50

Static Water Level: 5.04 mbtoc **Date:** 18/04/2019

Remarks: Stick up: 0.52m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion Diagram	Well Completion Notes
0			Alluvium: Alluvium/Gravel/Sand, red-brown to dark-grey gravels in a silty/sandy martix. Large calcrete pebbles and broken fragments of dolomite	0 5000 10000 15000 20000 25000	Injecting	0-34m = cement/bentonite grout	
10	Upper Calcrete		Calcrete: Light-brown, pink and white, contains small, rounded inclusions of quartz		Airlift: 3.5L/s, EC: 2950µS/cm, pH: 8.25, Foamy	0-39.5m = 50mm CL18 PVC Blank Casing	
20					Airlift: 8.0L/s, EC: 3440µS/cm, pH: 8.21, Foamy		
30					No yield		
40	Undiff. Tertiary		Gravel: Red-brown, mixed clasts of calcrete, dolomite and chert with ~20% pisolites in a silty/sandy matrix		Airlift: 12.0L/s, EC: 3610µS/cm, pH: 8.21, Light-brown	34-36m = bentonite seal	
50					Airlift: 12.5L/s, EC: 3790µS/cm, pH: 8.24, Light-brown	36-57m = gravel pack (3.2-6.4mm)	
60	CID/Pisolite		Pisolite: Dark-grey to dark-brown, magnetic, well-rounded pisolites with larger fragments of dolomite, chert and BIF		Hydro changeover- no yields recorded	39.5-58.5m = 50mm CL18 PVC Slotted Casing	
70						57-58.5m = bentonite seal	
80							
90							
100							
110							
120							

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COMPOSITE WELL LOG

Bore No: MDPZ7462C

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 21/03/19
Completed: 22/03/19
Drilled: Ausdrill NW
Logged By: TV

Method: DR
Fluid: Air
Bit Record: 0-35m = 241mm

Area: Mulga Downs
Elevation: 405 mAHD
Easting: 644802
Northing: 7548109
Projection: MGA94 Zone 50

Static Water Level: 5.19 mbtoc **Date:** 18/04/2019

Remarks: Stick up: 0.58m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion Diagram	Well Completion Notes
0			Clay: Red-brown, soft, sticky, massive clay	0 5000 10000 15000 20000 25000	Injecting, red-brown	0-6m = cement/bentonite grout	
10	Upper Calcrete		Alluvium: Alluvium/Gravel/Topsoil, red-brown, friable, silty sands (clays locally), containing clasts (some broken and angular) of dolomite		Injecting, yellow-brown	6-8m = bentonite seal	
20					Airlift: 7.0L/s, EC: 3100µS/cm, pH: 8.48, White/yellow-brown/ red-brown	0-21m = 50mm CL18 PVC Blank Casing	
30			Calcrete: Light-brown, yellow and dirty-white, containing small rounded inclusions of quartz		Airlift: 10.3L/s, EC: 3180µS/cm, pH: 8.47, Milky white	8-35m = gravel pack (3.2-6.4mm)	
40					Airlift: 12.2L/s, EC: 3370µS/cm, pH: 8.25, Light-brown	21-35m = 50mm CL18 PVC Slotted Casing	
50					Airlift: 12.3L/s, EC: 3520µS/cm, pH: 8.22, Very light-brown		
60							
70							
80							
90							
100							
110							
120							

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COMPOSITE WELL LOG

Bore No: MDPZ7463

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 30/03/2019
Completed: 1/04/2019
Drilled: Ausdrill NW
Logged By: ATS

Method: DR(0-82m)/DTH(82-88m)
Fluid: Air
Bit Record: 0-82m = 241mm
82-88m = 191mm

Area: Mulga Downs
Elevation: 405 mAHD
Easting: 642867
Northing: 7553588
Projection: MGA94 Zone 50

Static Water Level: 5.43 mbtoc **Date:** 12/04/2019

Remarks: Stick up: 0.28m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion Diagram	Well Completion Notes
0–10	Upper Calcrete		Clay: Dark red silty clay (90%) with lithics of chert and BIF (10%). Calcrete: Light brown, very soft with minor fragments of BIF and chert. Reacts strongly to acid.	0–25,000	No yield - AWT	0-3m = cement/bentonite grout; 3-5m = bentonite seal; 0-10.5m = 50mm CL18 PVC Bank Casing	
10–30	Undiff. Tertiary		Alluvium: Red/brown silty clayey matrix with lithics of BIF, chert and quartz. Clayey lense from 16-20m.		Airlift: 0.5L/s, EC: 4750µS/cm, pH: 8.28, Muddy; No yield; Airlift: 0.4L/s, EC: 2010µS/cm, pH: 8.35, Light-brown		
30–50	CID/Pisolite		Pisolite: Pisolite/CID- Dark red/brown, rounded pisolites. Medium-coarse grained with minor massive CID.		Airlift: 7.7L/s, EC: 6005µS/cm, pH: 8.05, Light-brown; Airlift: 8.5L/s, EC: 5500µS/cm, pH: 8.24, Light-brown; Airlift: 9.2L/s, EC: 5270µS/cm, pH: 8.25, Light-brown	5-82m = gravel pack (3.2-6.4mm); 10.5-85.5m = 50mm CL18 PVC Slotted Casing (2mm slots)	
50–70	Basal Calcrete		Calcrete: White, vuggy calcrete. Reacts moderately to acid. Moderately hard and fine grained.		Airlift: 10.0L/s, EC: 4750µS/cm, pH: 8.27, Light-brown; Airlift: 25.0L/s, EC: 4850µS/cm, pH: 8.31, Light-brown; Airlift: 25.0L/s, EC: 4720µS/cm, pH: 8.21, Light-brown; Airlift: 22.0L/s, EC: 5030µS/cm, pH: 8.32, Light-brown; Airlift: 22.0L/s, EC: 4940µS/cm, pH: 8.40, Light-brown		
70–90	Marra Mamba		Shale: Yellow weathered shale with dark grey chert. Chert: Light grey - dark grey chert with purple/pink/white shale. Chert: Dark grey chert with yellow goethite staining.		Airlift: 25.0L/s, EC: 6490µS/cm, pH: 8.21, Yellow; Airlift: 12.0L/s, EC: 9950µS/cm, pH: 8.26, Dark purple; Airlift: 35.0L/s, EC: 12050µS/cm, pH: 8.10, Dark purple	82-85.5m = gravel pack (3.2-6.4mm); Fallback	
90–100							

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COMPOSITE WELL LOG

Bore No: MDPZ7464

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

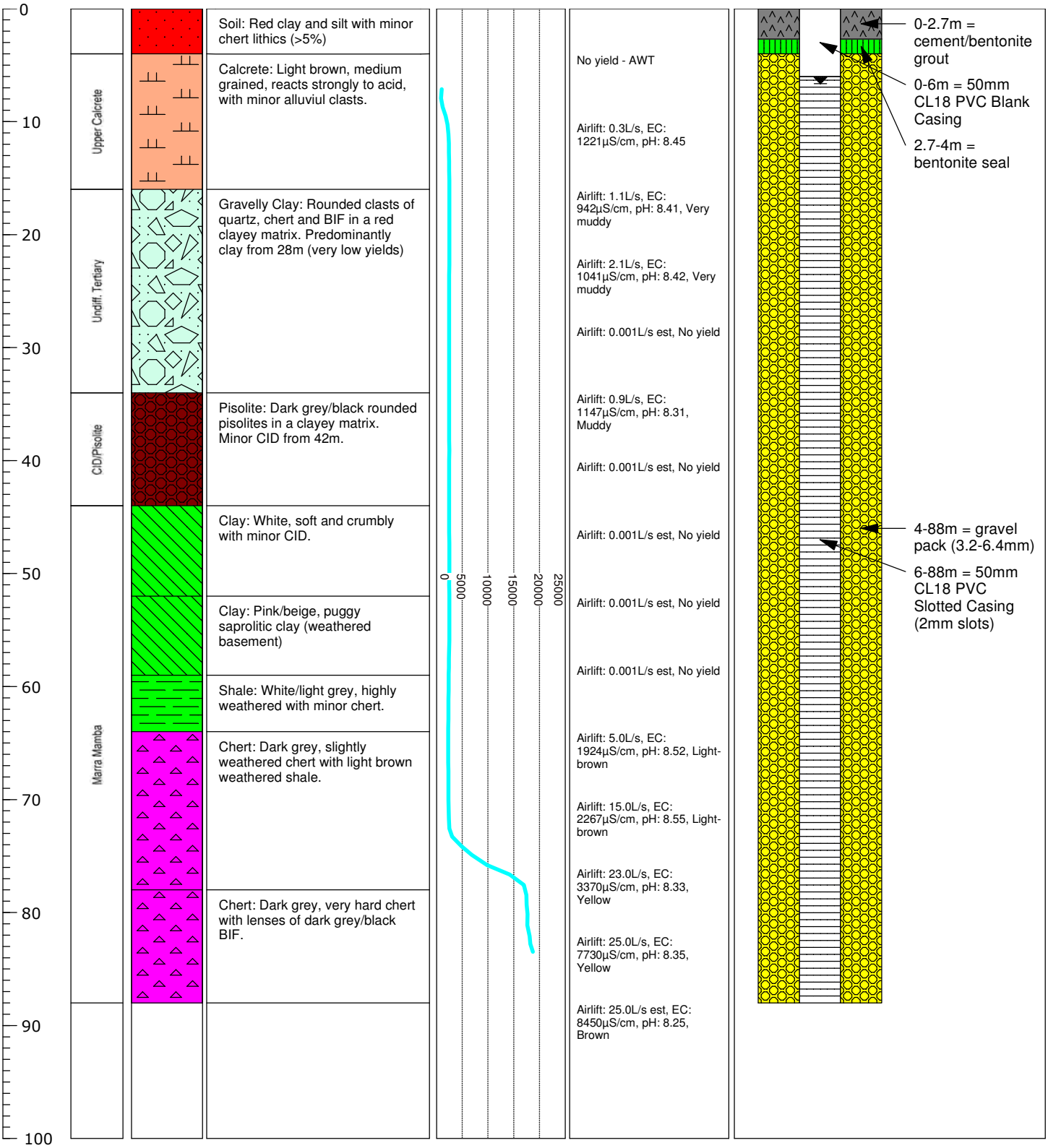
Commenced: 3/04/2019
Completed: 6/04/2019
Drilled: Ausdrill NW
Logged By: ATS

Method: DR
Fluid: Air
Bit Record: 0-88m = 241mm

Area: Mulga Downs
Elevation: 403 mAHD
Easting: 649944
Northing: 7552428
Projection: MGA94 Zone 50

Static Water Level: 6.65 mbtoc
Date: 15/04/2019
Remarks: Stick up: 0.28m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion Diagram	Well Completion Notes
0			Soil: Red clay and silt with minor chert lithics (>5%)		No yield - AWT		0-2.7m = cement/bentonite grout
10	Upper Calcrete		Calcrete: Light brown, medium grained, reacts strongly to acid, with minor alluvial clasts.		Airlift: 0.3L/s, EC: 1221µS/cm, pH: 8.45		0-6m = 50mm CL18 PVC Blank Casing
20	Undiff. Tertiary		Gravelly Clay: Rounded clasts of quartz, chert and BIF in a red clayey matrix. Predominantly clay from 28m (very low yields)		Airlift: 1.1L/s, EC: 942µS/cm, pH: 8.41, Very muddy		2.7-4m = bentonite seal
30					Airlift: 2.1L/s, EC: 1041µS/cm, pH: 8.42, Very muddy		
40	CID/Pisolite		Pisolite: Dark grey/black rounded pisolites in a clayey matrix. Minor CID from 42m.		Airlift: 0.001L/s est, No yield		
50	Marra Mamba		Clay: White, soft and crumbly with minor CID.		Airlift: 0.9L/s, EC: 1147µS/cm, pH: 8.31, Muddy		4-88m = gravel pack (3.2-6.4mm)
60			Clay: Pink/beige, puggy saprolitic clay (weathered basement)		Airlift: 0.001L/s est, No yield		6-88m = 50mm CL18 PVC Slotted Casing (2mm slots)
70			Shale: White/light grey, highly weathered with minor chert.		Airlift: 0.001L/s est, No yield		
80			Chert: Dark grey, slightly weathered chert with light brown weathered shale.		Airlift: 0.001L/s est, No yield		
90			Chert: Dark grey, very hard chert with lenses of dark grey/black BIF.		Airlift: 5.0L/s, EC: 1924µS/cm, pH: 8.52, Light-brown		
100					Airlift: 15.0L/s, EC: 2267µS/cm, pH: 8.55, Light-brown		
					Airlift: 23.0L/s, EC: 3370µS/cm, pH: 8.33, Yellow		
					Airlift: 25.0L/s, EC: 7730µS/cm, pH: 8.35, Yellow		
					Airlift: 25.0L/s est, EC: 8450µS/cm, pH: 8.25, Brown		



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COMPOSITE WELL LOG

Bore No: MDPZ7465

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 7/04/19
Completed: 10/04/19
Drilled: Ausdrill NW
Logged By: TV

Method: DR
Fluid: Air
Bit Record: 0-112m = 241mm

Area: Mulga Downs
Elevation: 420 mAHD
Easting: 670005
Northing: 7547881
Projection: MGA94 Zone 50

Static Water Level: 16.63 mbtoc **Date:** 22/04/2019

Remarks: Stick up: 0.52m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Gamma Log	Field Notes	Well Completion: Diagram	Well Completion: Notes
0	Undiff. Tertiary		Sand: Alluvium/Silt/Sand, Silty sands with ~10% subrounded coarse clastics	0 – 25,000	0 – 200	Ajacent to MDPZ0757	0-76.5m = cement/bentonite grout	
10			Silty Gravel: Alluvium/Gravel/Silt, Subround gravel clasts in silty matrix			Injecting, brown discharge		
20			Gravelly Silt: Alluvium/Silt/Pisolites, Cemented silts with ~20% rounded, magnetic pisolites and ~10% coarse clasts of Chert and BIF.			Injecting, brown discharge		
30			Gravel: Alluvium/Gravel, Multicoloured, coarse gravels. Mixed clasts of BIF, Chert and Shale. Base of alluvium			Injecting, brown discharge		
40	Marra Mamba		BIF: Dark-grey, yellow, red, strongly hydrated, vuggy, limonitic			Airlift: 0.5L/s, EC: 692µS/cm, pH: 8.73, Brown		
50			BIF: BIF/Chert, Yellow-brown to dark-grey, well-bedded, weakly weathered, interlayered BIF and Chert.			Airlift: 0.9L/s, EC: 865µS/cm, pH: 8.54, Brown		
60						Airlift: 1.4L/s, EC: 1396µS/cm, pH: 8.44, Brown		
70			Shale: Shale/Clay, Brown and yellow, soft, clayey, strongly weathered Shale			Airlift: 5.4L/s, EC: 1520µS/cm, pH: 8.41, Yellow		
80			Chert: Chert/BIF/Shale, Dark-grey, well-bedded, fresh, hard,			Airlift: >20L/s est, EC: 1533µS/cm, pH: 8.48 @45m	76.5-80m = bentonite seal	
90			Shale: Dark-grey to black, fresh, strongly laminated, carbonaceous, pyritic			Airlift: 5.4L/s, EC: 1743µS/cm, pH: 8.34, Light brown		
100						Airlift: 12.0L/s est, EC: 1778µS/cm, pH: 8.31, Light-brown		
110						Airlift: >20L/s est, EC: 2169µS/cm, pH 8.66, Dark-brown/yellow-brown		
120						Airlift: >20L/s est, EC: 2117µS/cm, pH 8.66, Dark-brown	80-111.5m = gravel pack (3.2-6.4mm)	
						Airlift: 15.0L/s est, EC: 2594µS/cm, pH: 8.43, Grey		
						Airlift: 15.0L/s est, EC: 2650µS/cm, pH: 8.54, Grey		
						Airlift: 15.0L/s est, EC: 2630µS/cm, pH: 8.53, Grey		
						Airlift: 18.0L/s est, EC: 2870µS/cm, pH: 8.45, Light grey		
						Airlift: 18.0L/s est, EC: 3150µS/cm, pH: 8.11, Grey	50mm CL18 PVC Slotted Casing (2mm slots)	
						Airlift: 18.0L/s est, EC: 3260µS/cm, pH: 8.24, Grey		
						Airlift: 18.0L/s est, EC: 3030µS/cm, pH: 8.10, Grey		

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COMPOSITE WELL LOG

Bore No: MDPZ7466

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 11/04/2019
Completed: 12/04/2019
Drilled: Ausdrill NW
Logged By: TV

Method: DR/DTH
Fluid: Air
Bit Record: 0-64.9m = 241mm

Area: Mulga Downs
Elevation: 439 mAHD
Easting: 671338
Northing: 7550528
Projection: MGA94 Zone 50

Static Water Level: 34.55 mbtoc **Date:** 15/04/2019

Remarks: Stick up: 0.55m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description
0 – 25	Marra Mamba		Chert: Chert/BIF, Yellow-brown, red-brown and grey, weakly weathered, well-bedded chert (70%) and BIF (30%)
25 – 30	Marra Mamba		Shale: Shale/Chert, Purple-grey, moderately weathered, laminated shale with minor chert interbeds. Some shale strongly weathered to clay
30 – 50	Marra Mamba		Chert: Chert/Shale, Purple-grey, hard. Mainly chert with a soft, clayey shale unit at 42-44m.
50 – 60	Marra Mamba		Chert: Chert/BIF, Dark-grey and purple, weakly weathered, vuggy in places
60 – 65	Jerinah		Shale: Dark-grey to black, fresh, finely laminated, carbonaceous shale
65 – 100	Jerinah		

EC (µS/cm): 0 – 25,000 (0, 5000, 10000, 15000, 20000, 25000)

Gamma Log: 0 – 200 (0, 50, 100, 150, 200)

Field Notes
Injecting with foam
Injecting with foam, Yellow/brown mud
Injecting with foam, Yellow/brown mud
Airlift: 0.1L/s, Red/brown, Mud
Airlift: 0.3L/s, EC: 834µS/cm, pH: 8.23, Red, Mud
Airlift: 0.3L/s, EC: 705µS/cm, pH: 8.01, Red, Mud
Airlift: 0.5L/s, EC: 892µS/cm, pH: 7.90, Red, Mud
Airlift: 4.7L/s, EC: 1082µS/cm, pH: 7.84, Grey/brown
Airlift: 4.5L/s, EC: 1211µS/cm, pH: 7.65, Red
Airlift: 4.8L/s, EC: 1419µS/cm, pH: 7.30, Red/brown to black
Airlift: 4.5L/s, EC: 1517µS/cm, pH: 7.39, Dark grey to black

Well Completion

Diagram	Notes
	0-28m = cement/bentonite grout
	50mm CL18 PVC Blank Casing
	28-30m = bentonite seal
	30-64.9m = gravel pack (3.2-6.4mm)
	50mm CL18 PVC Slotted Casing (2mm slots)

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COMPOSITE WELL LOG

Bore No: MDPZ7467

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 13/04/2019
Completed: 14/04/2019
Drilled: Ausdrill NW
Logged By: TV

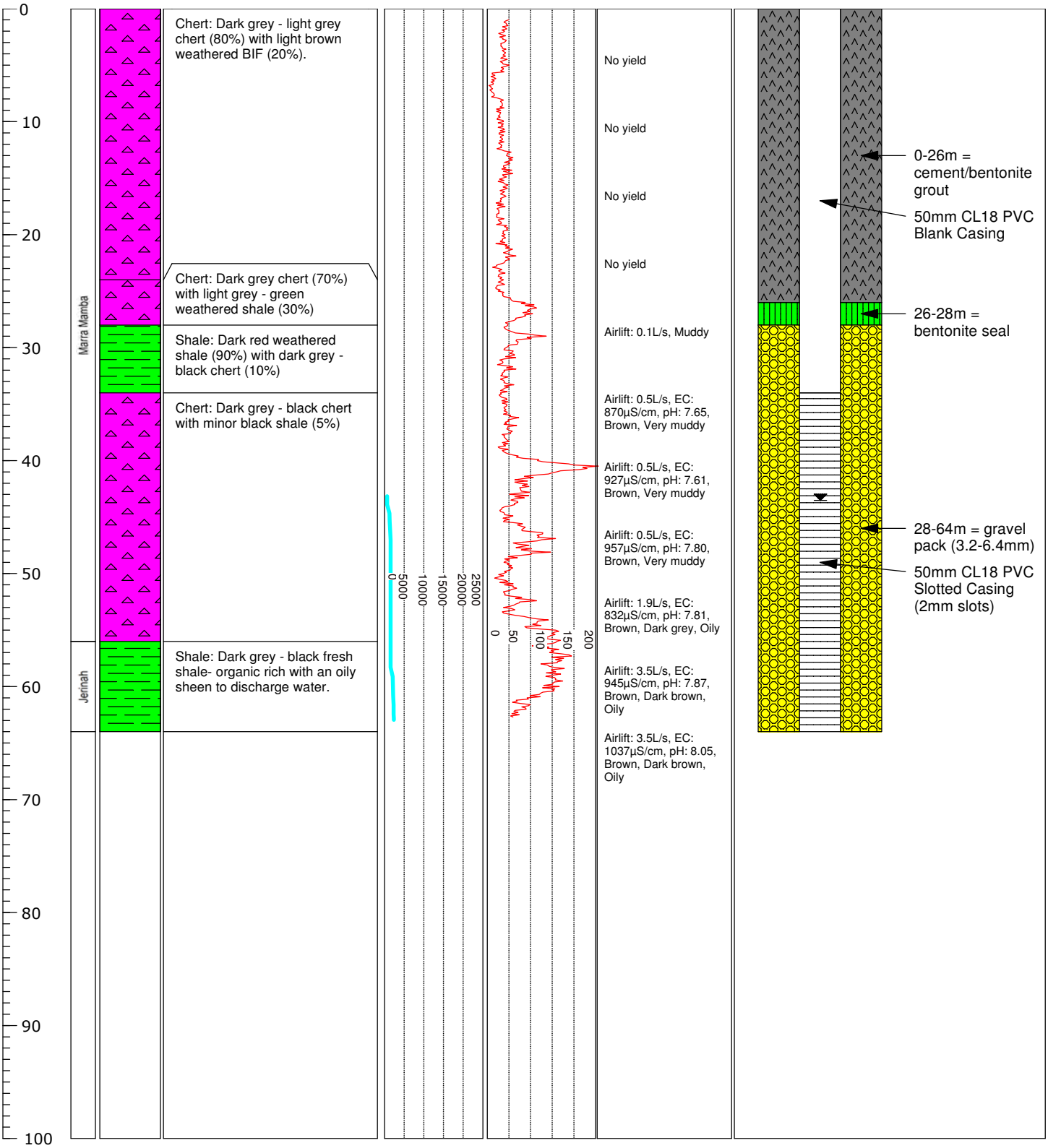
Method: DR/DTH
Fluid: Air
Bit Record: 0-64m = 241mm

Area: Mulga Downs
Elevation: 445 mAHD
Easting: 667657
Northing: 7552969
Projection: MGA94 Zone 50

Static Water Level: 43.53 mbtoc **Date:** 21/04/2019

Remarks: Stick up: 0.46m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Gamma Log	Field Notes	Well Completion Diagram	Well Completion Notes
0 – 26	Marra Mamba		Chert: Dark grey - light grey chert (80%) with light brown weathered BIF (20%).			No yield		0-26m = cement/bentonite grout; 50mm CL18 PVC Blank Casing
26 – 28	Marra Mamba		Chert: Dark grey chert (70%) with light grey - green weathered shale (30%)			No yield		26-28m = bentonite seal
28 – 30	Marra Mamba		Shale: Dark red weathered shale (90%) with dark grey - black chert (10%)			No yield		
30 – 57	Marra Mamba		Chert: Dark grey - black chert with minor black shale (5%)			Airlift: 0.1L/s, Muddy Airlift: 0.5L/s, EC: 870µS/cm, pH: 7.65, Brown, Very muddy Airlift: 0.5L/s, EC: 927µS/cm, pH: 7.61, Brown, Very muddy Airlift: 0.5L/s, EC: 957µS/cm, pH: 7.80, Brown, Very muddy Airlift: 1.9L/s, EC: 832µS/cm, pH: 7.81, Brown, Dark grey, Oily		28-64m = gravel pack (3.2-6.4mm); 50mm CL18 PVC Slotted Casing (2mm slots)
57 – 64	Jerinah		Shale: Dark grey - black fresh shale- organic rich with an oily sheen to discharge water.			Airlift: 3.5L/s, EC: 945µS/cm, pH: 7.87, Brown, Dark brown, Oily Airlift: 3.5L/s, EC: 1037µS/cm, pH: 8.05, Brown, Dark brown, Oily		



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COMPOSITE WELL LOG

Bore No: MDPZ7468A

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 15/04/2019
Completed: 17/04/2019
Drilled: Ausdrill NW
Logged By: TV

Method: DR(0-82m)/DTH(82-89m)
Fluid: Air
Bit Record: 0-82m = 241mm
82-89m = 191mm

Area: Mulga Downs
Elevation: 401 mAHD
Easting: 647191
Northing: 7551524
Projection: MGA94 Zone 50

Static Water Level: 4.96 mbtoc **Date:** 7/05/2019

Remarks: Stick up: 0.51m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion Diagram	Well Completion Notes
0 – 10	Upper Calcrete		Soil: Red/brown clay (90%) with chert and BIF clasts (10%). Calcrete: Light brown/beige, fine grained, soft, reacts with acid.	0 – 25,000	No yield - AWT Airlift: 0.3L/s, EC: 2023µS/cm, pH: 7.97, Brown, Muddy	0-64m = cement/bentonite grout 0-82m = 50mm CL18 PVC Blank Casing	
10 – 40	Undiff. Tertiary		Gravel: Assorted subrounded clasts of quartz, chert and BIF. Coarse grained and poorly sorted from 14-26m, becoming finer grained, more rounded and sorted from 26m.		Airlift: 0.7L/s, EC: 6008µS/cm, pH: 7.69, Brown, Muddy Airlift: 0.6L/s, EC: 3120µS/cm, pH: 7.92, Brown, muddy Airlift: 10.0L/s, EC: 10140µS/cm, pH: 7.81, Light brown Airlift: 17.5L/s, EC: 10005µS/cm, pH: 7.93, Light brown		
40 – 50	CID/Pisolite		Pisolite: Pisolite/CID, Dark grey/black pisolite. 'Coarsening up sequence'. Gradational boundary between alluvium and pisolite.	0, 5000, 10000, 15000, 20000, 25000	Airlift: 3.5L/s, EC: 7890µS/cm, pH: 7.86, Brown, Dark brown, Very muddy Airlift: 0.001L/s est, Dark brown		
50 – 60	Basal Calcrete		Calcrete: Silcrete/Calcrete, White - light pink weathered silcrete and/or calcrete. Very soft and 'waxy' texture. Goethite nodules from 56-64m.		Airlift: 1.0L/s, EC: 14650µS/cm, pH: 7.95, Light brown Airlift: 0.001L/s est, Creamy, Muddy	64-66m = bentonite seal	
60 – 90	Marra Mamba		Chert: Dark - Light grey chert with weathered white and pink shale. Shale content decreasing with depth. BIF: Dark grey/black fresh BIF with minor chert. Very hard, strongly magnetic.		Airlift: 0.001L/s est, White Airlift: 13.5L/s, EC: 16310µS/cm, pH: 8.11, Creamy Airlift: 21.0L/s, EC: 16590µS/cm, pH: 8.14, Brown, Pink/red Airlift: 25.0L/s est, EC: 17350µS/cm, pH: 8.17, Red/brown Airlift: 25.0L/s est, EC: 18360µS/cm, pH: 8.10, Light grey	66-89m = gravel pack (3.2-6.4mm) 82-89m = 50mm CL18 PVC Slotted Casing (2mm slots)	
90 – 100							

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COMPOSITE WELL LOG

Bore No: MDPZ7468B

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 17/04/2019
Completed: 19/04/2019
Drilled: Ausdrill NW
Logged By: TV

Method: DR
Fluid: Air
Bit Record: 0-65m = 241mm

Area: Mulga Downs
Elevation: 401 mAHD
Easting: 647195
Northing: 7551571
Projection: MGA94 Zone 50

Static Water Level: 4.98 mbtoc **Date:** 7/05/2019

Remarks: Stick up: 0.58m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion Diagram	Well Completion Notes
0 – 100	Upper Calcrete; Undiff. Tertiary; CID/Pisolite; Basal Calcrete; Marra.		Soil: Red/brown clay (90%) with chert and BIF clasts (10%). Calcrete: Light brown/beige, fine grained, soft, reacts with acid. Gravel: Assorted subrounded clasts of quartz, chert and BIF. Coarse grained and poorly sorted from 14-26m, becoming finer grained, more rounded and sorted from 26m. Pisolite: Pisolite/CID, Dark grey/black pisolite. 'Coarsening up sequence'. Gradational boundary between alluvium and pisolite. Calcrete: Silcrete/Calcrete, White - light pink weathered silcrete and/or calcrete. Very soft and 'waxy' texture. Goethite nodules from 56-64m. Chert: Dark - Light grey chert with weathered white and pink shale.	0 – 25,000	No yield - AWT Airlift: 2.2L/s, EC: 10510µS/cm, pH: 8.21, Light brown Airlift: 0.1L/s est, EC: 65908µS/cm, pH: 8.29, Muddy Airlift: 0.001L/s est, Muddy Airlift: 1.1L/s, EC: 9320µS/cm, pH: 8.22, Brown, Muddy Airlift: 15.2L/s, EC: 98105µS/cm, pH: 7.95, Muddy Airlift: 0.1L/s est Airlift: 0.5L/s, EC: 8530µS/cm, pH: 7.9 No yield Airlift: 4.1L/s, EC: 16000µS/cm, pH: 8.13, Milky Airlift: 8.5L/s, EC: 15350µS/cm, pH: 8.11, Milky	0-52m = cement/bentonite grout 0-56m = 50mm CL18 PVC Blank Casing 52-54m = bentonite seal 56-62m = 50mm CL18 PVC Slotted Casing (2mm slots) 54-65m = gravel pack (3.2-6.4mm) 62-65m = 50mm CL18 PVC Blank Casing	

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COMPOSITE WELL LOG

Bore No: MDPZ7468C

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 19/04/2019
Completed: 20/04/2019
Drilled: Ausdrill NW
Logged By: TV

Method: DR
Fluid: Air
Bit Record: 0-52m = 241mm

Area: Mulga Downs
Elevation: 401 mAHD
Easting: 647200
Northing: 7551579
Projection: MGA94 Zone 50

Static Water Level: 5.08 mbtoc
Date: 7/05/2019
Remarks: Stick up: 0.62m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion Diagram	Well Completion Notes
0 – 16	Upper Calcrete		Soil: Red/brown clay (90%) with chert and BIF clasts (10%). Calcrete: Light brown/beige, fine grained, soft, reacts with acid.	0 – 25,000	No yield data recorded	0-16m = cement/bentonite grout; 0-21.3m = 50mm CL18 PVC Blank Casing; 16-18m = bentonite seal; 18-52m = gravel pack (3.2-6.4mm); 21.3-51m = 50mm CL18 PVC Slotted Casing (2mm slots); 51-52m = 50mm CL18 PVC Blank Casing	
16 – 40	Undiff. Tertiary		Gravel: Assorted subrounded clasts of quartz, chert and BIF. Coarse grained and poorly sorted from 14-26m, becoming finer grained, more rounded and sorted from 26m.				
40 – 52	CID/Pisolite		Pisolite: Dark grey/black pisolite. 'Coarsening up sequence'. Gradational boundary between alluvium and pisolite. Calcrete: White - light pink weathered silcrete and/or calcrete. Very soft and 'waxy' texture.				

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COMPOSITE WELL LOG

Bore No: MDPZ7469A

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 22/04/2019
Completed: 25/04/2019
Drilled: Ausdrill NW
Logged By: TV

Method: DR(0-88m)/DTH(88-101m)
Fluid: Air
Bit Record: 0-88m = 241mm
88-101m = 191mm

Area: Mulga Downs
Elevation: 403 mAHD
Easting: 657312
Northing: 7550011
Projection: MGA94 Zone 50

Static Water Level: 4.01 mbtoc **Date:** 08/08/2019

Remarks: Stick up: 0.50m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion Diagram	Well Completion Notes
0–110	Undiff. Tertiary; CID/Pisolite; Basal Calcrete; Marra Mamba		Gravel: Alluvials/Calcrete/Silt, Light-brown to pinkish-white, mixed alluvials comprising friable, angular, porous, weakly reactive and subangular, hard, brown, highly reactive calcrete with subangular, weakly cemented, silt concretions and rare subrounded pebbles of shale and chert Gravel: Alluvials/Gravel, Red-brown, grey and white, very poorly sorted, subrounded gravels, sands and silts Gravel: Alluvials/Pisolites, Red-brown, well-rounded, magnetic pisolites with larger, friable, weakly cemented silts and rare, subrounded shale clasts Gravel: Alluvials/Gravel, Red-brown to dark-grey and white, mixed, coarse, poorly-sorted, subrounded to angular clasts of Chert and BIF Gravel: Alluvials/Pisolites/CID, Red-brown to dark-grey, well-rounded, magnetic pisolites with softer, friable, subrounded clasts of weakly cemented silt Silcrete: Silcrete/Calcrete, Pale-yellow to white, hard, chalcedonic, banded silcrete/chert becoming more friable and calcareous (reactive) towards base of unit Laterite: Hydrated hardcap, Dark-grey, brown, yellow, vuggy, subangular to angular. Minor yellow-white, shale/clay bands. Goethitic and limonitic. Clinker-like in places Shale: Dark-grey to black, finely bedded, weakly weathered, carbonaceous shale. Leaves oily sheen on water	0–25,000	AWT Airlift: 3.7L/s, EC: 3340µS/cm, pH: 7.61, Light brown, Clean Airlift: 4.1L/s, EC: 3820µS/cm, pH: 7.69, Brown, Muddy Airlift: 5.6L/s, EC: 2780µS/cm, pH: 8.01, Light brown, Clean Airlift: 5.6L/s, EC: 3260µS/cm, pH: 7.91, Light brown, Clean Airlift: 0.4L/s, EC: 1792µS/cm, pH: 8.02, Dark brown, Muddy Airlift: 5.1L/s, EC: 2720µS/cm, pH: 7.96, Dark brown Airlift: 1.8L/s, EC: 3060µS/cm, pH: 8.03, Dark brown, Clean Airlift: 0.5L/s, EC: 2860µS/cm, pH: 8.09, Dark brown, Muddy Airlift: 1.8L/s, EC: 2910µS/cm, pH: 8.24, Light brown/yellow Airlift: 1.0L/s, Too foamy to sample Airlift: 5.0L/s, EC: 3190µS/cm, pH: 8.36, Brown-yellow Airlift: 7.0L/s, EC: 3110µS/cm, pH: 8.32, Brown-green Airlift: 7.0L/s, EC: 3330µS/cm, pH: 8.34, Dark grey-brown Airlift: 16.8L/s, EC: 3250µS/cm, pH: 8.37, Dark-brown Airlift: 25.0L/s est, EC: 7600µS/cm, pH: 8.24, Black Airlift: 25.0L/s est, EC: 9780µS/cm, pH: 7.84, Dark grey Airlift: 25.0L/s est, EC: 10540µS/cm, pH: 7.64 @ 101m	0-8m = Backfill 0-93m = 50mm CL18 PVC Blank Casing 8.8-87.5m = cement/bentonite grout 87.5-90m = bentonite seal 90-101m = gravel pack (3.2-6.4mm) 93-101m = 50mm CL18 PVC Slotted Casing (2mm slots)	

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COMPOSITE WELL LOG

Bore No: MDPZ7469B

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 26/04/2019
Completed: 27/04/2019
Drilled: Ausdrill NW
Logged By: TV

Method: DR
Fluid: Air
Bit Record: 0-83m = 241mm

Area: Mulga Downs
Elevation: 403 mAHD
Easting: 657309
Northing: 7550029
Projection: MGA94 Zone 50

Static Water Level: 3.45 mbtoc
Date: 08/09/2019
Remarks: Stick up = 0.37m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion Diagram	Well Completion Notes
0	Undiff. Tertiary		Gravel: Alluvials/Calcrete/Gravel, pink and red-brown, angular, friable, weakly reactive calcrete (some harder, brown chips more reactive), with weakly cementedsilts and coarse, mixed gravels	0 – 25,000	Injecting, Pink foam	0-15.5m = Backfill	
10					Injecting, Pink foam		
20			Gravel: Alluvials/Gravels/Pisolites, red-brown, pink, grey and white, coarse, subrounded, poorly sorted gravels (mainly shale) with concretions of weakly cemented Fe- and Mn-rich silt. Minor, rounded, hard, magnetic pisolites		Airlift: 2.8L/s, EC: 3150µS/cm, pH: 8.45, Pink		
30					Airlift: <0.1L/s est, Pink, Mud	0-64m = 50mm CL18 PVC Blank Casing	
40	CID/Pisolite		Gravel: Alluvials/Pisolites, red-brown to dark-grey, rounded, hard, magnetic pisolites, well-sorted. Rare, subangular clasts of Shale and BIF		Airlift: 3.3L/s, EC: 2840µS/cm, pH: 8.15, Light pink-brown	15.5-55.5m = cement/bentonite grout	
50	Basal.		Silcrete: White and yellow, fine-grained, soft, soapy, weakly vuggy. Non-reactive to acid	0 5000 10000 15000 20000 25000	Airlift: 2.7L/s, EC: 3000µS/cm, pH: 8.31, Light pink-brown		
60	Marra Mamba		Laterite: Hydrated Hardcap, yellow-brown and grey, hard, vuggy, strongly weathered, limonitic and goethitic		EC: 2950µS/cm, pH: 8.55, Red-brown, Mud	55.5-57.8m = bentonite seal	
70			Laterite: Hydrated Hardcap/Clay, dark-grey, white and yellow, mixed Hardcap, Clay and Fault Gouge material		Airlift: <0.5L/s est, Red-brown, Mud	57.8-59.3m = gravel pack (3.2-6.4mm)	
80			Laterite: Hydrated Hardcap, yellow-brown and grey, hard, vuggy, strongly weathered, limonitic and goethitic		Airlift: 7.0L/s, EC: 2360µS/cm, pH: 8.43, White	59.3-61.5m = fallback material	
90					Airlift: <0.2L/s est, Yellow-brown, Mud	61.5-82m = gravel pack (3.2-6.4mm)	
100					Airlift: 10.3L/s, EC: 3170µS/cm, pH: 8.45, Pale yellow	64-82m = 50mm CL18 PVC Slotted Casing (2mm slots)	
110					Airlift: 12.2L/s, EC: 3310µS/cm, pH: 8.32, Pale yellow		
					Airlift: 15.0L/s est, EC: 3350µS/cm, pH: 8.43, Dark grey-brown		
					Airlift: 18.0L/s est, EC: 3280µS/cm, pH: 8.23, Dark grey-brown		

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COMPOSITE WELL LOG

Bore No: MDPZ7469C

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 28/04/2019
Completed: 29/04/2019
Drilled: Ausdrill NW
Logged By: TV

Method: DR
Fluid: Air
Bit Record: 0-53m = 241mm

Area: Mulga Downs
Elevation: 403 mAHD
Easting: 657316
Northing: 7550041
Projection: MGA94 Zone 50

Static Water Level: 3.49 mbtoc
Date: 08/09/2019
Remarks: Stick up = 0.53m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion Diagram	Well Completion Notes
0	Undiff. Tertiary		Gravel: Alluvium/Calcrete/Silt, red-brown to pale-yellow, friable, subangular, reactive calcrete and weakly-cemented, ferruginous and manganiferous silts	0 – 25,000	Injecting, Pink foam	0-4.4m = Backfill	
10					Injecting, Pink foam	2.4-5.5m = cement/bentonite grout	
20			Gravel: Alluvials/Gravel, multicoloured, poorly-sorted, subangular to subrounded, very coarse-grained gravels of Shale, Chert, BIF and Quartz. Rare pisolites		Airlift: 0.7L/s, EC: 2470µS/cm, pH: 8.12, Pink	0-10.5m = 50mm CL18 PVC Blank Casing	
30					Airlift: 2.6L/s, EC: 2760µS/cm, pH: 8.16, Light red-brown	5.5-6.8m = bentonite seal	
40	CID/Pisolite		Gravel: Alluvials/Pisolites/Gravel, red-brown and grey, medium-grained, rounded, well-sorted, magnetic pisolites with minor (<10%) subrounded-subangular clasts of BIF and Quartz		Airlift: 4.3L/s, EC: 2890µS/cm, pH: 8.19, Light red-brown	6.8-50.5m = gravel pack (3.2-6.4mm)	
50			Laterite: Hydrated Hardpan, yellow-brown, red and grey, subrounded, vuggy, strongly weathered, limonitic and goethitic	0 – 5000 – 10000 – 15000 – 20000 – 25000	Airlift: 2.5L/s, EC: 2860µS/cm, pH: 8.03, Red-brown	10.5-52.5m = 50mm CL18 PVC Slotted Casing (2mm slots)	
60					Airlift: 2.5L/s, EC: 2780µS/cm, Red-brown		
70					Airlift: <0.2L/s est, Red-brown, Mud		
80							
90							
100					Airlift: <0.2L/s est, EC: 2000µS/cm, pH: 8.15, Red-brown, Mud	Fallback	
110							

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COMPOSITE WELL LOG

Bore No: MDPZ7470A

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 19/07/2019
Completed: 22/07/2019
Drilled: Ausdrill NW
Logged By: TV

Method: DR / DTH
Fluid: Air
Bit Record: 0-58m = 241mm
58-108m = 191mm

Area: Mulga Downs
Elevation: 404.8 mAHD
Easting: 661397
Northing: 7546377
Projection: MGA94 Zone 50

Static Water Level: 4.51 mbtoc **Date:** 09/08/2019

Remarks: Stick up: 0.89

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Gamma Log	Field Notes	Well Completion Diagram	Well Completion Notes
0	Alluv		Alluvium: Red- and yellow-brown, poorly sorted, mixed alluvials with minor calcrete and pisolites	0 – 25,000	0 – 200	Airlift: 1.4 L/s, EC: 4000 uS/cm, pH: 7.86, Pink		
10	Upper Calcrete		Calcrete: White to light, pink-brown. Strong quartz veining at 8-10m. FWS @ 9m			Airlift: 4.6 L/s, EC: 4300 uS/cm, pH: 8.30, Pink-brown		
20	Undiff. Tertiary		Silty Gravel: Red-brown to dark-grey, comprising rounded, magnetic pisolites and broken fragments of larger chert and shale in a weakly cemented silty matrix. Clayey layer from 42-44m			Airlift: 6.0 L/s, EC: 4380 uS/cm, pH: 8.22, Light brown		
30						Airlift: 7.0 L/s, EC: 4530 uS/cm, pH: 8.51, Light brown	0-58m = cement/bentonite grout	
40						Airlift: 8.5 L/s, EC: 5000 uS/cm, pH: n/a, Light brown	0-74m = 50mm CL18 Blank PVC Casing	
50	CID/Pisolite		Pisolitic Clay: Dark-grey magnetic pisolites in a clayey matrix. Minor fragments of chert and shale			Airlift: 8.5 L/s, EC: 5030 uS/cm, pH: n/a, Light brown Injection: 42-44m		
	Basal Calcrete		Calcrete: White and yellow-brown, very hard, crystalline containing round inclusions of smoky quartz			Airlift: 10.0 L/s, EC: 5020 uS/cm, pH: n/a, Light brown		
60	Marra Mamba		BIF: Grey-brown, hard, banded, vuggy, limonitic and goethitic, iridescent, containing quartz bands			Airlift: 17.0 L/s, EC: 5050 uS/cm, pH: n/a, Milky		
						Airlift: 17.0 L/s, EC: 5150 uS/cm, pH: n/a, Light grey		
70			BIF: Yellow-brown, grey and white, interbedded vuggy BIF, hard siliceous chert and soft, strongly weathered shale, mostly altered to clay			Airlift: 17.0 L/s, EC: 5190 uS/cm, pH: n/a, Light grey	62.6-64.3m = bentonite seal	
						Airlift: 25.0 L/s, EC: 5200 uS/cm, pH: n/a, Yellow-brown		
80			BIF: Yellow-brown and grey, interbedded BIF and chert. Hard, siliceous, well-bedded			Airlift: 25.0 L/s, EC: 5200 uS/cm, pH: n/a, Yellow-brown		
						Airlift: >30.0 L/s, EC: 5260 uS/cm, pH: n/a, Yellow-brown	64.3-104m = gravel pack (3.2-6.4mm)	
90						Airlift: >30.0 L/s, EC: 5330 uS/cm, pH: n/a, Grey	74-104m = 50mm CL18 Slotted PVC Casing (2mm slots)	
						Airlift: >30.0 L/s, EC: 5460 uS/cm, pH: n/a, Grey		
100						Airlift: >30.0 L/s, EC: 6890 uS/cm, pH: n/a, Light grey		
						Airlift: >30.0 L/s, EC: 7050 uS/cm, pH: n/a, Light grey	104-108m = Fallback	
110								

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COMPOSITE WELL LOG

Bore No: MDPZ7470B

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 22/07/2019
Completed: 24/07/2019
Drilled: Ausdrill NW
Logged By: TV

Method: DR / DTH
Fluid: Air
Bit Record: 0-46m = 241mm
46-49m = 191mm

Area: Mulga Downs
Elevation: 404.8 mAHD
Easting: 661388
Northing: 7546376
Projection: MGA94 Zone 50

Static Water Level: 4.62 mbtoc **Date:** 09/08/2019

Remarks: Stick up: 0.96

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion Diagram	Well Completion Notes
0 – 110	Upper Calcrete; Undiff. Tertiary		Soil: Alluvium/Pisolites/Silt, Red-brown, fine- to coarse-grained, mixed, subrounded pebbles and pisolites in a weakly cemented silty matrix Calcrete: Contains rounded quartz inclusions. Reacts strongly to acid Gravel: Alluvials/Pisolites/Silt, Red- and yellow-brown, mixed alluvials (subrounded fragments of chert and shale) with well-rounded pisolites in a weakly cemented silty matrix Calcrete: White, crystalline, hard	0 – 25,000	Airlift: 2.7L/s, EC: 4000µS/cm, pH: n/a, Pink-brown- FWS @ 9m Airlift: 3.3L/s, EC: 4480µS/cm, pH: n/a, Dark brown Airlift: 6.0L/s, EC: 4630µS/cm, pH: n/a, Dark brown Airlift: 6.0L/s, EC: 4900µS/cm, pH: n/a, Brown Airlift: 8.0L/s, EC: 4790µS/cm, pH: n/a, Brown Airlift: 8.0L/s, EC: 4860µS/cm, pH: n/a, Dark red/brown Airlift: 10.0L/s, EC: 4990µS/cm, pH: n/a, Dark red/brown Airlift: 10.0L/s, EC: 5100µS/cm, pH: n/a, Dark red/brown	0-22.5m = cement/bentonite grout 0-29.1m = 50mm CL18 Blank PVC Casing 22.5-25m = bentonite seal 24-49.1m = gravel pack (3.2-6.4mm) 29.1-49.1m = 50mm CL18 Slotted PVC Casing (2mm slots) Bentonite Seal at bottom of hole	

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COMPOSITE WELL LOG

Bore No: MDPZ7470C

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 24/07/2019
Completed: 24/07/2019
Drilled: Ausdrill NW
Logged By: TV

Method: DR
Fluid: Air
Bit Record: 0-23m = 241mm

Area: Mulga Downs
Elevation: 404.7 mAHD
Easting: 661379
Northing: 7546376
Projection: MGA94 Zone 50

Static Water Level: 4.56 mbtoc **Date:** 09/08/2019

Remarks: Stick up: 0.95

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0			Soil: Alluvium/Pisolites/Silt, Red-brown, poorly sorted, subrounded pebbles of chert and shale with rounded, magnetic pisolites in a weakly cemented silty matrix	0 – 25,000	Airlift: 1.2L/s, EC: 4160µS/cm, pH: n/a, Pink-brown- FWS @ 8m	0-5.2m = cement/bentonite grout	
10	Upper Calcrete		Calcrete: Pink, brown and white, crystalline calcrete containing rounded quartz inclusions. Reacts strongly to acid		Airlift: 4.3L/s, EC: 4480µS/cm, pH: n/a, Brown	0-11m = 50mm CL18 Blank PVC Casing	
20					Airlift: 6.0L/s, EC: 4860µS/cm, pH: n/a, Brown	5.2-7m = bentonite seal	
30						7-23m = gravel pack (3.2-6.4mm)	
40						11-23m = 50mm CL18 Slotted PVC Casing (2mm slots)	
50				0 5000 10000 15000 20000 25000			
60							
70							
80							
90							
100				0 5000 10000 15000 20000 25000			
110							

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COMPOSITE WELL LOG

Bore No: MDPZ7471A

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 26/07/2019
Completed: 28/07/2019
Drilled: Ausdrill NW
Logged By: TV

Method: 0-58m = DR, 58-78 = DTH
Fluid: Air
Bit Record: 0-78m = 241mm

Area: Mulga Downs
Elevation: 402.7 mAHD
Easting: 646671
Northing: 7549390
Projection: MGA94 Zone 50

Static Water Level: 4.51 mbtoc **Date:** 7/09/2019

Remarks: Stick up = 0.9m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion Diagram	Well Completion Notes
0			Clay: Red-brown, soft, sticky, massive clay.				
10	Upper Calcrete		Calcrete: Green-yellow/brown/pink, vuggy, crystalline. Contains rounded quartz inclusions. Reacts strongly to acid.		Airlift: 1.9 L/s, EC: 5490 uS/cm		
20	Undiff. Tertiary		Silt: Red-brown and yellow-brown, weakly cemented, friable silts. Top part is very clayey. Manganiferous staining in places.		Airlift: 3.3 L/s, EC: 6750 uS/cm		
30			Silty Gravel: Red-brown, yellow-brown and grey, subangular, poorly sorted, mixed gravels of Cheret, Shale and BIF in a weakly cemented silty matrix.		Airlift: 3.9 L/s, EC: 6800 uS/cm Airlift: 2 L/s, EC: 6820 uS/cm	0-61.5m = backfill 0-68m = 50mm CL18 PVC Blank Casing	
40	CID/Pisolite		Silt: Red-brown, well-sorted silts with rounded, magnetic pisolites.		Airlift: 6 L/s, EC: 7390 uS/cm Airlift: 8.5 L/s, EC: 7870 uS/cm		
50	Basal Calcrete		Calcrete: White and yellow, crystalline, massive hard calcrete. Reacts strongly to acid.	0 5000 10000 15000 20000 25000	Airlift: 8.5 L/s, EC: 8700 uS/cm		
60	Marra Mamba		BIF: Dark-grey to blue-black, fine-grained and poorly bedded. Iridescent and shiny with conchoidal fractures. Specularrite in places, also limonite and goethite staining.		Airlift: 17 L/s, EC: 8540 uS/cm Airlift: 17 L/s, EC: 8140 uS/cm	61.5-64m = bentonite seal	
70			Shale: Yellow-brown, soft, sticky clay/weathered shale with angular fragments of BIF/Ore.		Airlift: 23 L/s, EC: 8000 uS/cm	64-78m = gravel pack (3.2-6.4mm) 68-78m = 50mm CL18 PVC Slotted Casing	
80					Airlift: 44 L/s, EC: 8260 uS/cm Airlift: 44 L/s		
90							
100							

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COMPOSITE WELL LOG

Bore No: MDPZ7471B

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 28/07/2019
Completed: 29/07/2019
Drilled: Ausdrill NW
Logged By: ATS

Method: 0-52m = DR, 52-60 = DTH
Fluid: Air
Bit Record: 0-52m = 241mm
52-60m = 191mm

Area: Mulga Downs
Elevation: 402.68 mAHD
Easting: 646661
Northing: 7549391
Projection: MGA94 Zone 50

Static Water Level: 4.65 mbtoc **Date:** 7/09/2019

Remarks: Stick up = 1.1m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion Diagram	Well Completion Notes
0 – 100	Upper Calcrete; Undiff. Tertiary; CID/Pisolite; Basal Calcrete		Clay: Red-brown, soft, sticky massive clay Calcrete: Brown, white and greenish-yellow, friable. Reacts strongly to acid Silt: Alluvials/Silt, Red-brown, weakly cemented friable silt with manganiferous staining locally Gravelly Silt: Alluvials/Gravel/Silt, Red-yellow-brown and grey, mixed, poorly-sorted, subrounded gravels of Chert, Shale and BIF in a weakly cemented silty matrix Silt: Alluvials/Silt, Red-brown, weakly cemented friable silt with manganiferous staining locally Gravelly Silt: Alluvials/Gravel/Silt, Red-yellow-brown and grey, mixed, poorly-sorted, subrounded gravels of Chert, Shale and BIF in a weakly cemented silty matrix Silt: Alluvials/Silt/Pisolites, Red-brown, weakly cemented silt containing hard, rounded, magnetic pisolites Calcrete: Calcrete, White and greenish-grey, hard, massive, crystalline calcrete containing round quartz inclusions. Reacts strongly to acid	0 – 25,000 (0, 5000, 10000, 15000, 20000, 25000)	Airlift: 2.2 L/s, EC: 5050 uS/cm Airlift: 3.4 L/s, EC: 6890 uS/cm Airlift: 1.2 L/s, EC: 6570 uS/cm Airlift: 3.4 L/s, EC: 7480 uS/cm Airlift: 2.7 L/s, EC: 6240 uS/cm Airlift: 3 L/s, EC: 7660 uS/cm Airlift: 9 L/s, EC: 8550 uS/cm Airlift: 16 L/s, EC: 8320 uS/cm Airlift: 7 L/s, EC: 8150 uS/cm	0-23.2 = cement 0-30m = 50mm CL18 PVC Blank Casing 23.2-25m = bentonite seal 25-60m = gravel pack (3.2-6.4mm) 30-60m = 50mm CL18 PVC Slotted Casing	

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COMPOSITE WELL LOG

Bore No: MDPZ7471C

Client: JBS&G / HPPL

Project: Mulga East Baseline Investigations

Commenced: 30/07/2019
Completed: 31/07/2019
Drilled: Ausdrill NW
Logged By: TV

Method: 0-21m = DR
Fluid: Air
Bit Record: 0-21m = 241mm

Area: Mulga Downs
Elevation: 402.6 mAHD
Easting: 646681
Northing: 7549389
Projection: MGA94 Zone 50

Static Water Level: 4.79 mbtoc **Date:** 7/09/2019

Remarks: Stick up = 0.93m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0			Clay: Red-brown, soft, sticky, massive clay	0 – 25,000		0-5.4m = cement 0-11m = 50mm CL18 PVC Blank Casing 5.4-7m = bentonite seal 7-21m = gravel pack (3.2-6.4mm) 11-21m = 50mm CL18 PVC Slotted Casing	
10	Upper Calcrete		Calcrete: Light-brown, pink and white, crystalline, vuggy with round quartz inclusions. Reacts strongly wiith acid				
20					Airlift: 1.8 L/s, EC: 6000 uS/cm		
30					Airlift: 4.4 L/s, EC: 6550 uS/cm		
40							
50				0, 5000, 10000, 15000, 20000, 25000			
60							
70							
80							
90							
100							

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COMPOSITE WELL LOG

Bore No: MDPZ9201

Client: Roy Hill

Project: Mulga Downs PFS Investigation

Commenced: 07/07/2021
Completed: 09/07/2021
Drilled: Pentium Hydro
Logged By: CS

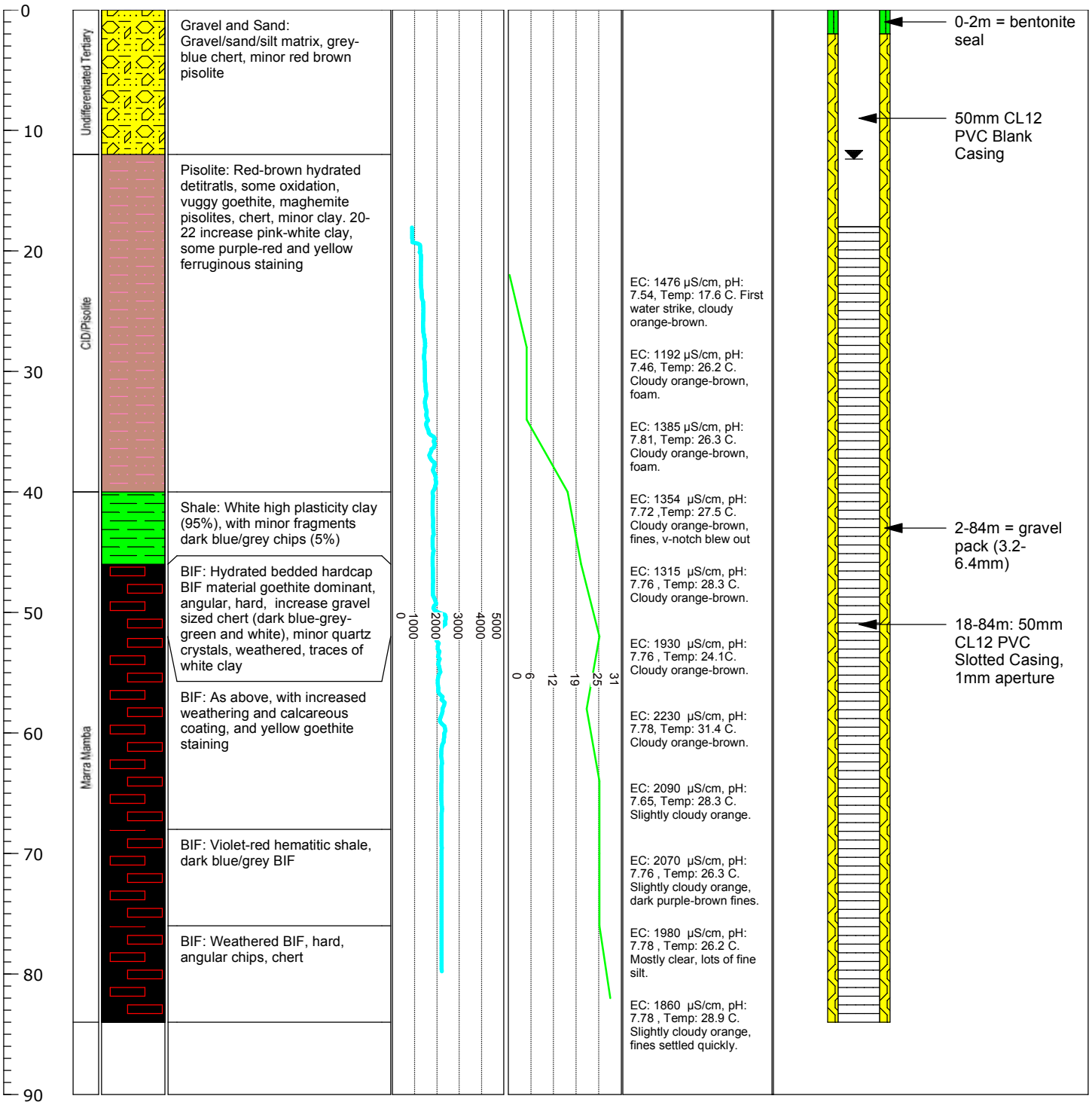
Method: DR
Fluid: Air
Bit Record: 0-84m = 230mm

Area: Mulga East
GL Elevation: 414.44 mAHD
Easting: 665349
Northing: 7549601
Projection: MGA94 Zone 50

Static Water Level: 12.85 mbtoc
Date: 10/08/2021

Remarks: Stick up = 0.46m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Drilling Yield (L/s)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0	Undifferentiated Tertiary		Gravel and Sand: Gravel/sand/silt matrix, grey-blue chert, minor red brown pisolite			EC: 1476 µS/cm, pH: 7.54, Temp: 17.6 C. First water strike, cloudy orange-brown.	0-2m = bentonite seal	
10							50mm CL12 PVC Blank Casing	
20	CID/Pisolite		Pisolite: Red-brown hydrated detitratls, some oxidation, vuggy goethite, maghemite pisolites, chert, minor clay. 20-22 increase pink-white clay, some purple-red and yellow ferruginous staining			EC: 1192 µS/cm, pH: 7.46, Temp: 26.2 C. Cloudy orange-brown, foam.		
30						EC: 1385 µS/cm, pH: 7.81, Temp: 26.3 C. Cloudy orange-brown, foam.		
40	Marra Mamba		Shale: White high plasticity clay (95%), with minor fragments dark blue/grey chips (5%)			EC: 1354 µS/cm, pH: 7.72 ,Temp: 27.5 C. Cloudy orange-brown, fines, v-notch blew out		
50			BIF: Hydrated bedded hardcap BIF material goethite dominant, angular, hard, increase gravel sized chert (dark blue-grey-green and white), minor quartz crystals, weathered, traces of white clay			EC: 1315 µS/cm, pH: 7.76 , Temp: 28.3 C. Cloudy orange-brown.	2-84m = gravel pack (3.2-6.4mm)	
60			BIF: As above, with increased weathering and calcareous coating, and yellow goethite staining			EC: 1930 µS/cm, pH: 7.76 , Temp: 24.1C. Cloudy orange-brown.	18-84m: 50mm CL12 PVC Slotted Casing, 1mm aperture	
70			BIF: Violet-red hematitic shale, dark blue/grey BIF			EC: 2230 µS/cm, pH: 7.78, Temp: 31.4 C. Cloudy orange-brown.		
80			BIF: Weathered BIF, hard, angular chips, chert			EC: 2090 µS/cm, pH: 7.65, Temp: 28.3 C. Slightly cloudy orange.		
90						EC: 2070 µS/cm, pH: 7.76 , Temp: 26.3 C. Slightly cloudy orange, dark purple-brown fines.		
						EC: 1980 µS/cm, pH: 7.78 , Temp: 26.2 C. Mostly clear, lots of fine silt.		
						EC: 1860 µS/cm, pH: 7.78 , Temp: 28.9 C. Slightly cloudy orange, fines settled quickly.		



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COMPOSITE WELL LOG

Bore No: MDPZ9202

Client: Roy Hill

Project: Mulga Downs PFS Investigation

Commenced: 09/07/2021
Completed: 13/07/2021
Drilled: Pentium Hydro
Logged By: CS

Method: DR
Fluid: Air
Bit Record: 0-88m = 230mm

Area: Mulga East
GL Elevation: 421.46 mAHD
Easting: 668073
Northing: 7549439
Projection: MGA94 Zone 50

Static Water Level: 19.42 mbtoc
Date: 13/07/2021

Remarks: Stick up = 0.24m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Drilling Yield (L/s)	Field Notes	Well Completion Diagram	Well Completion Notes
0 – 10	Undifferentiated Tertiary		Clay and Silt: Poorly sorted, clay silt matrix, redbn and blue grey sa to sr, chert (8-10m v hard, ground up chips)				0-2m = bentonite seal	
10 – 20	Undifferentiated Tertiary		Clay and Silt: As above increasing white soft clays and red hematitic shales				50mm CL12 PVC Blank Casing	
30	CID/Pisolite		Pisolite: Maghemite pisolites red brown well rounded highly magnetic, minor hematite CID and traces white clay					
40	CID/Pisolite		CID: Yellow to red brown clasts, white and purple staining and calc infill, vuggy, mod hard, minor gov conch fract			EC: 1207 µS/cm, pH:7.84, Temp: 29.6 C. Muddy brown, half foam.		
	CID/Pisolite		Pisolite: Maghemite pisolite			EC: 1200 µS/cm, pH:7.61, Temp: 28.5 C. Muddy brown, half foam.		
50	CID/Pisolite		CID: Vitreous goethite and hematitic clasts vuggy with goe infill, friable, ranging size fissile to large clasts, majority yellow brown, with 10-20% shales, gov, pink shl 54-56, white shale 60-62	0 1000 2000 3000 4000 5000	0 6 12 19 25 31	EC: 956 µS/cm, pH: 7.79, Temp: 22.4 C. Brown, viscous, foamy.	2-88m = gravel pack (3.2-6.4mm)	
60	Marra Mamba		BIF: Bedded blue grey angular hematite, minor goe brown 2mm to 4cm, much of sample ground smaller, minor clays, mineralisation hem at 70-76, blue dark redb streak, 10% ferrug shales red-purple mod hard			EC: 1069 µS/cm, pH: 7.60, Temp: 26.1 C. Brown, opaque.	16-88m: 50mm CL12 PVC Slotted Casing, 1mm aperture	
	Marra Mamba					EC: 1081 µS/cm, pH: 7.55, Temp: 28.3 C. Brown, opaque.		
70	Marra Mamba					EC: 1135 µS/cm, pH: 7.54, Temp: 29.1 C. Light yellow brown, opaque.		
	Marra Mamba					EC: 1118 µS/cm, pH: 7.57, Temp: 29.9 C. Light yellow brown, opaque.		
80	Marra Mamba		Shale: Red/wht shale 90% highly weathered, chert			EC: 1139 µS/cm, pH: 7.57, Temp: 29.3 C. Dark grey-brown, opaque.		
	Jeerinah		Shale: 80% dark grey to black shale 2-5cm rounded, massive. 10% redbn hematitic shale.			EC: 1132 µS/cm, pH: 7.73, Temp: 28.6 C. Dark grey, opaque.		
90								

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COMPOSITE WELL LOG

Bore No: MDPZ9203

Client: Roy Hill

Project: Mulga Downs PFS Investigation

Commenced: 13/07/2021
Completed: 16/07/2021
Drilled: Pentium Hydro
Logged By: CS

Method: DR
Fluid: Air
Bit Record: 0-76m = 230mm

Area: Mulga East
GL Elevation: 420.83 mAHD
Easting: 666865
Northing: 7550118
Projection: MGA94 Zone 50

Static Water Level: 19.24 mbtoc
Date: 10/08/2021

Remarks: Stick up = 0.57m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Drilling Yield (L/s)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0	Undifferentiated Tertiary		Gravel and Sand: Red-brown gravel/sand/silt matrix, yellow goethite staining, quartz crystals, grey-blue chert, medium hard to soft shales, poorly sorted, subrounded to subangular				0-2m = bentonite seal	
10	CID/Pisolite		Pisolite: Red-brown 1-4mm maghemite pisolites rounded				50mm CL12 PVC Blank Casing	
20			CID: Dark grey-bown vitreous goethite vuggy clasts angular to subangular with limonitic coating and infill, medium hard			EC: 259 µS/cm, pH: 7.51, Temp: 29.9 C. Orange-brown, opaque.		
30			CID: Scree as above, increasing goethite, white and pink clay and friable hematite, white calcrete			EC: 666 µS/cm, pH: 7.65, Temp: 28.9 C. Red-brown, opaque, foam.		
40	Marra Mamba		BIF: Bedded chert blue-grey to red-brown, goethite hematite chert bands, green to grey chert, red shale/clay, yellow goethite			EC: 569 µS/cm, pH: 7.57, Temp: 29.0 C. Yellow-brown, opaque, foam.		
			Shale: Pink bown clay 90% soft, minor hematite and goethite			EC: 481 µS/cm, pH: 7.43, Temp: 29.3 C. Brown, opaque.	2-76m = gravel pack (3.2-6.4mm)	
50			Shale: Yellow, red and purple clay/shales			EC: 324 µS/cm, pH: 7.41, Temp: 28.1 C. Red-brown, opaque.		
			BIF: Blue angular bif hard, cherty, min, minor red and purple shales and quartz crystals.	0 1000 2000 3000 4000 5000	0 6 12 19 25 31	EC: 555 µS/cm, pH: 7.41, Temp: 28.5 C. Brown to red-brown, opaque.	16-76m = 50mm CL12 PVC Slotted Casing, 1mm aperture	
60			BIF: Yellow-brown ochreous goethite, white shale and bedded hematite/chert			EC: 544 µS/cm, pH: 7.41, Temp: 28.5 C. Oramge-brown, opaque.		
			Shale: Red and pink shale, limonitic clay and staining, hematitie and goethite angular mod to hard			EC: 562 µS/cm, pH: 7.48, Temp: 28.6 C. Orange-brown, opaque.		
70			BIF: Yellow goethitic coating and ferruginised shales 80%, blue angular chert 20%.			EC: 708 µS/cm, pH: 7.57, Temp: 26.9 C. Orange-brown, opaque.		
			BIF: Yellow hydrated goethite and clay/weathered shale, quartz/chert.			EC: 644 µS/cm, pH: 7.54, Temp: 27.4 C. Dark grey-brown.		
80			BIF: Mineralised goethite, grey-white shales high plasticity clay, minor manganese					
			Shale: Black shale, weathered, soft, black stain					
90								

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COMPOSITE WELL LOG

Bore No: MDPZ9204

Client: Roy Hill

Project: Mulga Downs PFS Investigation

Commenced: 16/07/2021
Completed: 20/07/2021
Drilled: Pentium Hydro
Logged By: AS

Method: DR/OH
Fluid: Air
Bit Record: 0-94m = 230mm
94-100m = 190mm

Area: Mulga East
GL Elevation: 413.29 mAHD
Easting: 666361
Northing: 7548461
Projection: MGA94 Zone 50

Static Water Level: 11.73 mbtoc
Date: 10/08/2021

Remarks: Stick up = 0.48m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Drilling Yield (L/s)	Field Notes	Well Completion Diagram	Well Completion Notes
0 – 100	Undifferentiated Tertiary / CID/Pisolite / Marra Mamba		Gravel: Sand sized clasts comprising chert, quartz and ferruginous lithics. Rounded-angular, poorly sorted in a red silty/clayey matrix. Smaller clast size from 10-16m. Pisolite: Dark grey/black, fine - coarse grained (0.1-10mm), moderately sorted, rounded, highly magnetic. Minor CID at 40m. CID: Red-brown and black with metallic lustre, vuggy, friable, high iron content CID: Yellow/light pink, fairly soft CID with minimal iron content. Shale: Beige/white clay, often 'gritty', interbedded with minor chert and BIF. BIF: Dark grey with a purple tinge, flaky and soft. Moderately magnetic. Shale: Dark red/brown clay with interbedded BIF Chert: Dark grey with brown staining, hard	0, 1000, 2000, 3000, 4000, 5000	0, 6, 12, 18, 24, 30	FWS - Mud. EC: 753 µS/cm, pH: 7.75. Dark brown, very muddy. EC: 2050 µS/cm, pH: 7.66. Brown/red. EC: 2060 µS/cm, pH: 7.78. EC: 2450 µS/cm, pH: 7.84. EC: 2840 µS/cm, pH: 7.85. EC: 2860 µS/cm, pH: 7.87. EC: 2720 µS/cm, pH: 7.89. Light brown. EC: 2690 µS/cm, pH: 8.02. Switch to OH, light brown. EC: 2740 µS/cm, pH: 8.05. Purple-brown. EC: 2670 µS/cm, pH: 7.92. DR - Dark red, murky. EC: 2660 µS/cm, pH: 8.10. Brown, clear. EC: 2370 µS/cm, pH: 8.15. Dark brown.	0-2m = bentonite seal 50mm CL12 PVC Blank Casing 2-100m = gravel pack (3.2-6.4mm) 16-100m = 50mm CL12 PVC Slotted Casing, 1mm aperture	

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COMPOSITE WELL LOG

Bore No: MDPZ9205

Client: Roy Hill

Project: Mulga East PFS Investigations

Commenced: 20/07/2021
Completed: 24/07/2021
Drilled: Pentium Hydro
Logged By: AS

Method: DR/DTH
Fluid: Air
Bit Record: 0-34m = 230mm
34-70m = 190mm

Area: Mulga East
GL Elevation: 418.50 mAHD
Easting: 672010
Northing: 7548259
Projection: MGA94_Z50

Static Water Level: 11.72 mbtoc
Date: 10/08/2021

Remarks: Stick up = 0.53m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Drilling Yield (L/s)	Field Notes	Well Completion Diagram	Well Completion Notes
0 – 80	Undiff; CID Pisolite; Marra Mamba		Sand and Silt: Sand sized clasts comprising chert and quartz in a silty clayey matrix. Minor magnetic material. Rounded-angular, poorly sorted. Pisolite: Fine to coarse grained, well rounded, moderately sorted, highly magnetic. Red coated, dark grey/black interior. Pisolite: Red/brown, soft and friable CID with minor pisolites Chert: Red-brown-pink, highly weathered BIF: Yellow, magnetite rich with minor pink/red interbedded chert. Chert: Dark grey, very hard with pink clay band at 49m. BIF: Dark grey, magnetite rich with chert interbeds. Calcite vein/bed at 59m. Shale: Black, very soft with minor chert.	0, 1000, 2000, 3000, 4000, 5000	0, 4, 8, 12, 16, 20	FWS, OH from 22m EC: 1001 µS/cm, pH: 7.4. Dark brown. EC: 935 µS/cm, pH: 7.68. Milky red/brown. EC: 950 µS/cm, pH: 7.31. Brown, clearish. EC: 930 µS/cm, pH: 7.47. Brown clearish. EC: 1119 µS/cm, pH: 8.01. Brown clearish. EC: 1390 µS/cm, pH: 7.13. Very slow drilling through hard cherts, water becoming more grey. EC: 1373 µS/cm, pH: 7.86. Black. EC: 1334 µS/cm, pH: 8.04. Dark grey.	Blank PVC CL18, 100mm 0-70m = Gravel Pack (3.2-6.4mm) 16-70m = Slotted 100mm PVC CL18, 1mm aperture	

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COMPOSITE WELL LOG

Bore No: MDPZ9206

Client: Roy Hill

Project: Mulga Downs PFS Investigation

Commenced: 24/07/2021
Completed: 28/07/2021
Drilled: Pentium Hydro
Logged By: CS

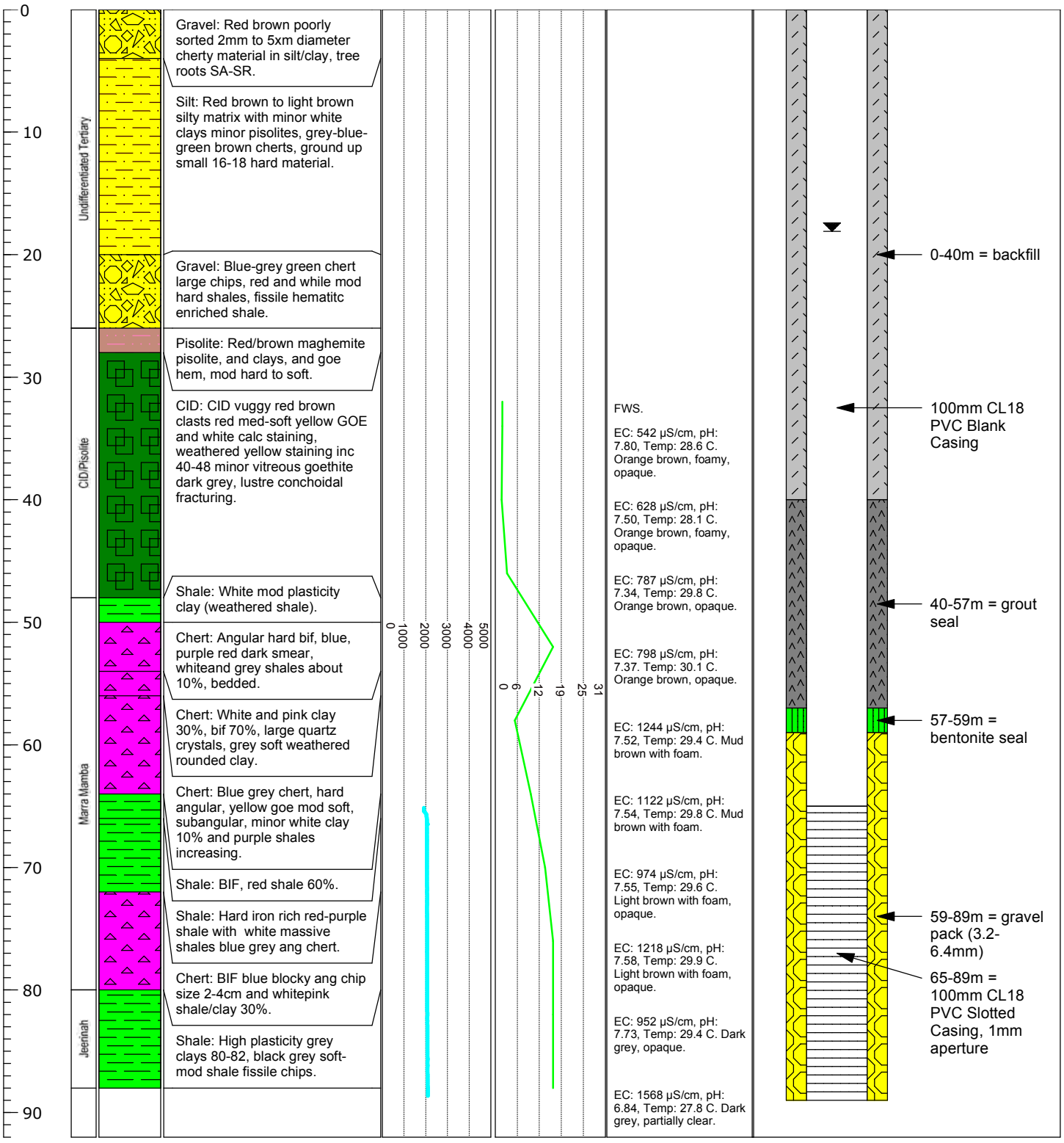
Method: DR
Fluid: Air
Bit Record: 0-89m = 230mm

Area: Mulga East
GL Elevation: 421.16 mAHD
Easting: 669177
Northing: 7549127
Projection: MGA94 Zone 50

Static Water Level: 18.60 mbtoc
Date: 10/08/2021

Remarks: Stick up = 0.50m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Drilling Yield (L/s)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0–1	Undifferentiated Tertiary		Gravel: Red brown poorly sorted 2mm to 5xm diameter cherty material in silt/clay, tree roots SA-SR.					
1–20	Undifferentiated Tertiary		Silt: Red brown to light brown silty matrix with minor white clays minor pisolites, grey-blue-green brown cherts, ground up small 16-18 hard material.					
20–25	Undifferentiated Tertiary		Gravel: Blue-grey green chert large chips, red and while mod hard shales, fissile hematitc enriched shale.					
25–30	CID/Pisolite		Pisolite: Red/brown maghemite pisolite, and clays, and goe hem, mod hard to soft.					
30–40	CID/Pisolite		CID: CID vuggy red brown clasts red med-soft yellow GOE and white calc staining, weathered yellow staining inc 40-48 minor vitreous goethite dark grey, lustre conchoidal fracturing.					
40–50	Marra Mamba		Shale: White mod plasticity clay (weathered shale).					
50–55	Marra Mamba		Chert: Angular hard bif, blue, purple red dark smear, whiteand grey shales about 10%, bedded.					
55–60	Marra Mamba		Chert: White and pink clay 30%, bif 70%, large quartz crystals, grey soft weathered rounded clay.					
60–70	Marra Mamba		Chert: Blue grey chert, hard angular, yellow goe mod soft, subangular, minor white clay 10% and purple shales increasing.					
70–72	Marra Mamba		Shale: BIF, red shale 60%.					
72–80	Marra Mamba		Shale: Hard iron rich red-purple shale with white massive shales blue grey ang chert.					
80–82	Jeerinah		Chert: BIF blue blocky ang chip size 2-4cm and whitepink shale/clay 30%.					
82–90	Jeerinah		Shale: High plasticity grey clays 80-82, black grey soft-mod shale fissile chips.					



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COMPOSITE WELL LOG

Bore No: MDPZ9207

Client: Roy Hill

Project: Mulga Downs PFS Investigation

Commenced: 31/07/2021
Completed: 3/08/2021
Drilled: Pentium Hydro
Logged By: CS

Method: DR
Fluid: Air
Bit Record: 0-77m = 230mm

Area: Mulga East
GL Elevation: 423.16 mAHD
Easting: 661988
Northing: 7552119
Projection: MGA94 Zone 50

Static Water Level: 22.57 mbtoc
Date: 7/08/2021

Remarks: Stick up = 0.55m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Drilling Yield (L/s)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0 – 80	Undifferentiated Te; CID/PL; Marra Mamba; Jeerinah		Gravel: Redbrown clay/silt matrix with 2-4mm chert, minor maghemite pisolites and blue-grey low magnetic material, plant roots. Rounded to sub-angular chips porly sorted.	0, 1000, 2000, 3000, 4000, 5000	0, 6, 12, 19, 25, 31	EC: 597uS/cm, pH: 7.92, Temp: 30.5°C, Orange brown, opaque	0-2m = bentonite seal	
			CID: Yellow goethitic chips, vuggy goethite clasts, minor hematite, angular hard, chert			EC: 617uS/cm, pH: 7.93, Temp: 27.1°C, Orange brown, opaque, foam	100mm CL18 PVC Blank Casing	
			BIF: Grey, red, yellow and minor blue-grey chips, siliceous banded goethite, blocky angular, red ferruginised shale with chert, much of sample ground to fine chips, hard drilling. 16-20m quartz crystals, 18-20m minor white-brown clay.			EC: 645uS/cm, pH: 7.87, Temp: 27.7°C, Orange brown, opaque, foam		
			Chert: Multicoloured chert and siliceous goethite (red, yellow, blue, grey-green). 50% clay/shale mod plasticity red-brown from 20-22m, yellow-brown 22-28m, red-purple 28-30m.			EC: 656uS/cm, pH: 7.74, Temp: 27.4°C, Light brown tinge, semitransparent	2-76.5m = gravel pack (3.2-6.4mm)	
			Chert: Dark blue-grey chert, angular, very hard, ferruginous red shale sub rounded. Yellow, pink and white soft shale/clay. Minor quartz crystals 42-44m.			EC: 675uS/cm, pH: 7.71, Temp: 29.6°C, Light brown tinge, semitransparent	16.5-76.5m = 100mm CL18 PVC Slotted Casing, 1mm aperture	
			Shale: Red/brown/grey fissile shale with black, angular, hard chert.			EC: 699uS/cm, pH: 7.79, Temp: 29.1°C, Light brown tinge, semitransparent		
			Chert: Brown/light brown goethite with red and grey shale and blue/grey hard, angular chert.			EC: 691uS/cm, pH: 7.71, Temp: 30°C, Light brown tinge, semitransparent		
			Shale: Black, breakable, fissile shale with pyrite.			EC: 694uS/cm, pH: 7.89, Temp: 31.5°C, Light brown tinge, semitransparent	76.5-77m = Gravel	

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COMPOSITE WELL LOG

Bore No: MDPZ9208

Client: Roy Hill

Project: Mulga Downs PFS Investigation

Commenced: 4/08/2021
Completed: 7/08/2021
Drilled: Pentium Hydro
Logged By: AS

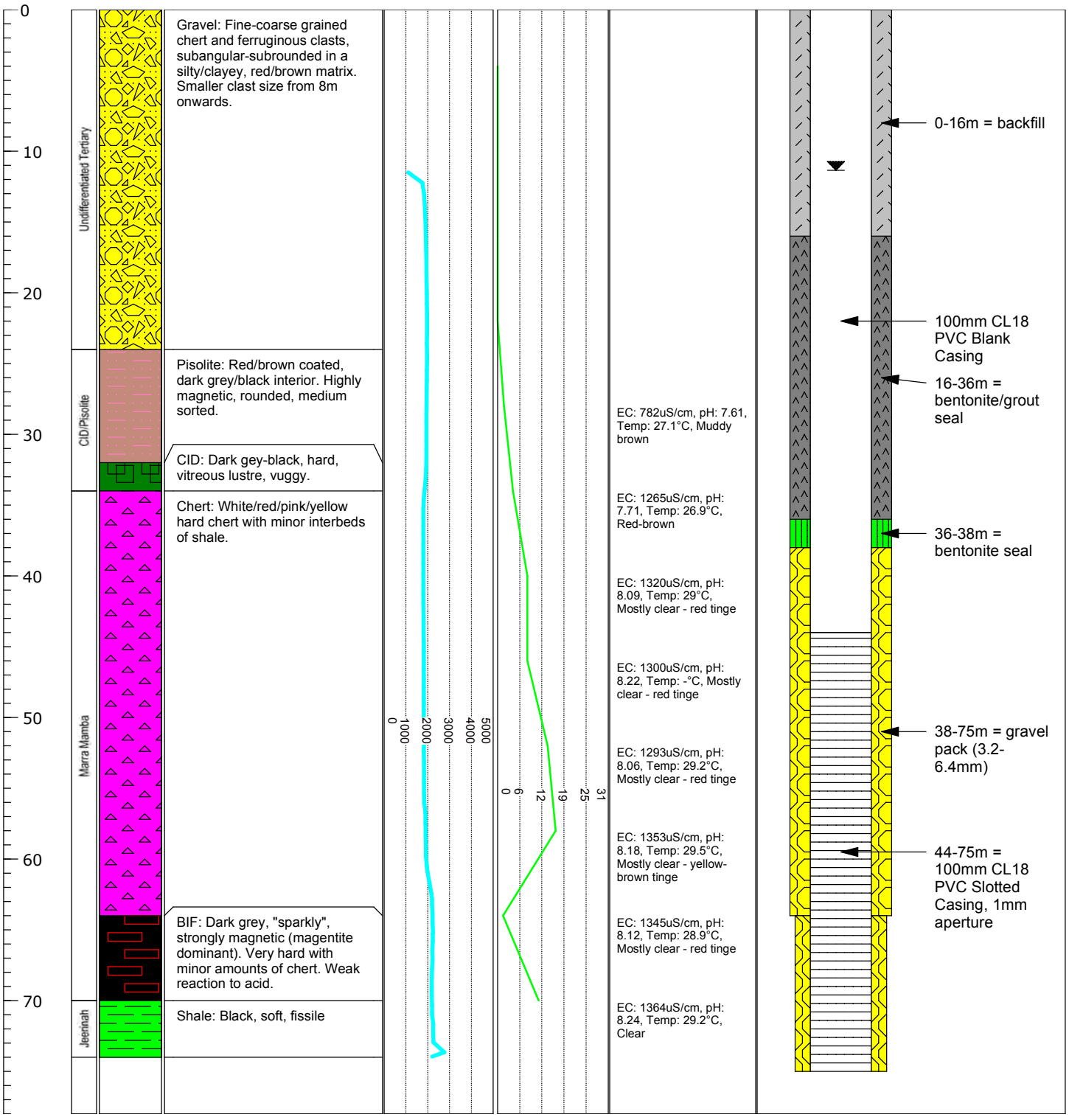
Method: DR / DTH
Fluid: Air
Bit Record: 0-64m = 230mm
64-75m = 190mm

Area: Mulga East
GL Elevation: 412.10 mAHD
Easting: 661329
Northing: 7550554
Projection: MGA94 Zone 50

Static Water Level: 11.85 mbtoc
Date: 10/08/2021

Remarks: Stick up = 0.50m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Drilling Yield (L/s)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0 – 10	Undifferentiated Tertiary		Gravel: Fine-coarse grained chert and ferruginous clasts, subangular-subrounded in a silty/clayey, red/brown matrix. Smaller clast size from 8m onwards.			EC: 782uS/cm, pH: 7.61, Temp: 27.1°C, Muddy brown	0-16m = backfill	
10 – 30	CID/Pisolite		Pisolite: Red/brown coated, dark grey/black interior. Highly magnetic, rounded, medium sorted.			EC: 1265uS/cm, pH: 7.71, Temp: 26.9°C, Red-brown	100mm CL18 PVC Blank Casing; 16-36m = bentonite/grout seal	
30 – 32	CID/Pisolite		CID: Dark gey-black, hard, vitreous lustre, vuggy.			EC: 1320uS/cm, pH: 8.09, Temp: 29°C, Mostly clear - red tinge	36-38m = bentonite seal	
32 – 50	Marra Mamba		Chert: White/red/pink/yellow hard chert with minor interbeds of shale.			EC: 1300uS/cm, pH: 8.22, Temp: -°C, Mostly clear - red tinge	38-75m = gravel pack (3.2-6.4mm)	
50 – 70	Marra Mamba		BIF: Dark grey, "sparkly", strongly magnetic (magentite dominant). Very hard with minor amounts of chert. Weak reaction to acid.			EC: 1293uS/cm, pH: 8.06, Temp: 29.2°C, Mostly clear - red tinge; EC: 1353uS/cm, pH: 8.18, Temp: 29.5°C, Mostly clear - yellow-brown tinge	44-75m = 100mm CL18 PVC Slotted Casing, 1mm aperture	
70 – 75	Jeerinah		Shale: Black, soft, fissile			EC: 1345uS/cm, pH: 8.12, Temp: 28.9°C, Mostly clear - red tinge; EC: 1364uS/cm, pH: 8.24, Temp: 29.2°C, Clear		



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COMPOSITE WELL LOG

Bore No: MDPZ9209

Client: Roy Hill

Project: Mulga Downs PFS Investigation

Commenced: 8/08/2021
Completed: 11/08/2021
Drilled: Pentium Hydro
Logged By: AS

Method: DR / DTH
Fluid: Air
Bit Record: 0-47m = 230mm
47-70m = 190mm

Area: Mulga East
GL Elevation: 419.09 mAHD
Easting: 664776
Northing: 7550535
Projection: MGA94 Zone 50

Static Water Level: 17.63 mbtoc
Date: 12/08/2021

Remarks: Stick up = XX m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Drilling Yield (L/s)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0–70	Undifferentiated Tertiary; CID/Pisolite; Marra Mamba; Jeerinah		Gravel: Fine-coarse grained chert and ferruginous clasts with minor quartz, subangular-subrounded in a silty/clayey, red/brown matrix. Pisolite: Red/brown, highly magnetic, fine-medium grained, poorly sorted with clay/silt. CID: Dark gey-black/brown-red, fairly soft, non-magnetic (minimal iron content). Chert: Yellow/brown stained chert with concoidal fracturing. Interbeds of minor brown/yellow soft shale. BIF: Dark grey/brown, strongly magnetic (predominantley magnetite) with minor chert and shale. Shale: Yellow/green, soft and clayey at 38m and 46m. Hard chert band at 42m. BIF: Light grey and "sparkly", very hard, strongly magnetic with a weak reaction to acid (dolomitic). Minor grey chert interbeds. Shale: Black, soft, fissile. Interbeds of dolomitic shales.	0, 1000, 2000, 3000, 4000, 5000	0, 6, 12, 19, 25, 31	EC: 460uS/cm, pH: 8.32, Temp: N.R.°C, Light brown EC: 525uS/cm, pH: 7.98, Temp: 29.5°C, Light brown EC: 440uS/cm, pH: 7.75, Temp: 28.2°C, Light brown EC: 462uS/cm, pH: 7.96, Temp: 28.7°C, Milky brown EC: 445uS/cm, pH: 7.79, Temp: 30°C, clear EC: 446uS/cm, pH: 8.18, Temp: 29.6°C, Clearish/yellow EC: 462uS/cm, pH: 7.85, Temp: 28.9°C, clearish/light brown EC: 462uS/cm, pH: 7.7, Temp: 28.8°C, clearish/light brown	0-20m = bentonite/grout seal 100mm CL18 PVC Blank Casing 20-22m = bentonite seal 22-74m = gravel pack (3.2-6.4mm) 28-70m = 100mm CL18 PVC Slotted Casing, 1mm aperture.

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COMPOSITE WELL LOG

Bore No: MDPZ9210

Client: Roy Hill

Project: Mulga Downs PFS Investigation

Commenced: 11/08/2021
Completed: 14/08/2021
Drilled: Pentium Hydro
Logged By: CS

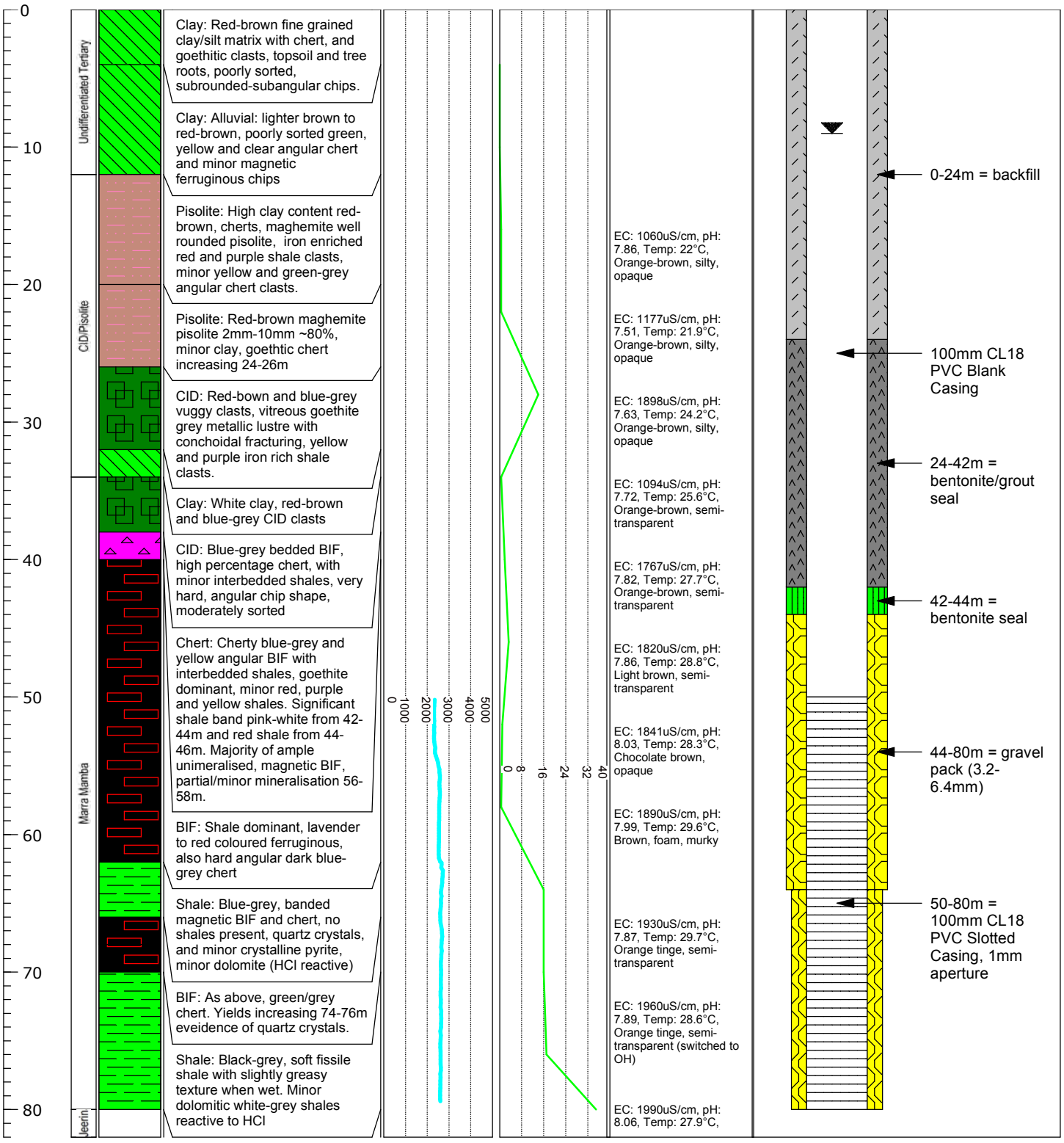
Method: DR / DTH
Fluid: Air
Bit Record: 0-64m = 230mm
64-80m = 190mm

Area: Mulga East
GL Elevation: 410.28 mAHD
Easting: 660323
Northing: 7550147
Projection: MGA94 Zone 50

Static Water Level: 9.46 mbtoc
Date: 16/08/2021

Remarks: Stick up = 0.45m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Drilling Yield (L/s)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0	Undifferentiated Tertiary		Clay: Red-brown fine grained clay/silt matrix with chert, and goethitic clasts, topsoil and tree roots, poorly sorted, subrounded-subangular chips.					
10			Clay: Alluvial: lighter brown to red-brown, poorly sorted green, yellow and clear angular chert and minor magnetic ferruginous chips					
20	CID/Pisolite		Pisolite: High clay content red-brown, cherts, maghemite well rounded pisolite, iron enriched red and purple shale clasts, minor yellow and green-grey angular chert clasts.			EC: 1060uS/cm, pH: 7.86, Temp: 22°C, Orange-brown, silty, opaque		
			Pisolite: Red-brown maghemite pisolite 2mm-10mm ~80%, minor clay, goethtic chert increasing 24-26m			EC: 1177uS/cm, pH: 7.51, Temp: 21.9°C, Orange-brown, silty, opaque		
30			CID: Red-bown and blue-grey vuggy clasts, vitreous goethite grey metallic lustre with conchoidal fracturing, yellow and purple iron rich shale clasts.			EC: 1898uS/cm, pH: 7.63, Temp: 24.2°C, Orange-brown, silty, opaque		
			Clay: White clay, red-brown and blue-grey CID clasts			EC: 1094uS/cm, pH: 7.72, Temp: 25.6°C, Orange-brown, semi-transparent		
40			CID: Blue-grey bedded BIF, high percentage chert, with minor interbedded shales, very hard, angular chip shape, moderately sorted			EC: 1767uS/cm, pH: 7.82, Temp: 27.7°C, Orange-brown, semi-transparent		
	Marra Mamba		Chert: Cherty blue-grey and yellow angular BIF with interbedded shales, goethite dominant, minor red, purple and yellow shales. Significant shale band pink-white from 42-44m and red shale from 44-46m. Majority of ample unimeralised, magnetic BIF, partial/minor mineralisation 56-58m.			EC: 1820uS/cm, pH: 7.86, Temp: 28.8°C, Light brown, semi-transparent		
50						EC: 1841uS/cm, pH: 8.03, Temp: 28.3°C, Chocolate brown, opaque		
			BIF: Shale dominant, lavender to red coloured ferruginous, also hard angular dark blue-grey chert			EC: 1890uS/cm, pH: 7.99, Temp: 29.6°C, Brown, foam, murky		
60			Shale: Blue-grey, banded magnetic BIF and chert, no shales present, quartz crystals, and minor crystalline pyrite, minor dolomite (HCl reactive)			EC: 1930uS/cm, pH: 7.87, Temp: 29.7°C, Orange tinge, semi-transparent		
			BIF: As above, green/grey chert. Yields increasing 74-76m eveidence of quartz crystals.			EC: 1960uS/cm, pH: 7.89, Temp: 28.6°C, Orange tinge, semi-transparent (switched to OH)		
70			Shale: Black-grey, soft fissile shale with slightly greasy texture when wet. Minor dolomitic white-grey shales reactive to HCl					
80	Jeerin					EC: 1990uS/cm, pH: 8.06, Temp: 27.9°C,		



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COMPOSITE WELL LOG

Bore No: MDPZ9211

Client: Roy Hill

Project: Mulga East PFS Investigations

Commenced: 12/09/2021
Completed: 17/09/2021
Drilled: Pentiumn Hydro
Logged By: AS

Method: DR / DTH
Fluid: Air
Bit Record: 0 - 82m = DR
82m - 130m = DTH

Area: Malay Well
GL Elevation: 403.88mAHD
Easting: 656000
Northing: 7545396
Projection: MGA94_Z50

Static Water Level: 3.89mbtoc
Date: 23/09/2021
Remarks: PVC stick up = 0.8

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Drilling Yield (L/s)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0 – 130	Upper Calcrete / CID Pisolite / Basal Crete / Paraburdoo		Calcrete: Beige/red to brown calcrete. Hard, fine grained, massive with bands of very hard silcrete at 22m and 38m. Pisolite: Dark brown, rounded pisolites. Medium-coarse grained with clay and minor vuggy CID. CID: Light brown/yellow CID (waste). Soft and friable with minor yellow pisolites. Calcrete: White/yellow/brown, very hard calcrete with calcite and silcrete veining. Hardcap: Dark grey, Moderately vuggy, brown goethite staining, weakly magnetic. Trace amounts of brown clay. Dolomite: Light grey/brown, weathered dolomite. Dolomite: Light grey, crystalline, very hard. Shale: Light brown, weathered dolomitic shale with brown stained chert and BIF. Dolomite: Light grey, crystalline, very hard.	0 5000 10000 15000 20000 25000	0 8 16 24 32 40		0-2m = Cement surface seal 100mm PVC CL18 Blank Casing 2-130m = Gravel Pack 34-130m = 100mm PVC CL18 Slotted Casing, 1mm aperture	

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COMPOSITE WELL LOG

Bore No: MDPZ9212D

Client: Roy Hill

Project: Mulga Downs PFS Investigation

Commenced: 654400
Completed: 7546690
Drilled: Pentium Hydro
Logged By: CS

Method: DR / DTH
Fluid: Air
Bit Record: 0-100m = 230mm
100-120m = 190mm

Area: Malay Well
GL Elevation: 405.17 mAHD
Easting: 654400
Northing: 7546689
Projection: MGA94 Zone 50

Static Water Level: 6.28 mbtoc
Date: 2/10/2021

Remarks: Stick up = 0.40m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Drilling Yield (L/s)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0	Upper Calcrete		Calcrete: Red/brown silt, white calcrete, minor clay to 2m then white, vuggy, weathered.			EC: 16000uS/cm, pH: 8.03, Temp: 27.9°C, Beige tinge, cloudy		
10			Calcrete: Pink-orange coating of white/beige & green khaki coarse grained calcrete, increase in low plasticity clay content 4-8m, 12-14m, 18-20m.			EC: 16100uS/cm, pH: 7.8, Temp: 28.9°C, Orange tinge, nearly transparent		
20						EC: 15100uS/cm, pH: 7.92, Temp: 28.9°C, Orange tinge, nearly transparent		
30			Calcrete: Pink-orange & white calcrete with minor glassy silcrete, minor black/brown rounded shales.			EC: 16100uS/cm, pH: 7.98, Temp: 28.5°C, Orange tinge, nearly transparent		
40	Undiff. Tertiary		Gravel: Red-brown, poorly sorted mix - vuggy calcrete, silcrete, shales interbedded with chert, minor goethite.			EC: 16300uS/cm, pH: 7.96, Temp: 29.3°C, Orange, cloudy		
50	CID Pis		Pisolite: Red/brown pisolite, magnetic & non-magnetic, minor white calcrete. Siliceous goethite 48-50m.			EC: 16400uS/cm, pH: 7.94, Temp: 28.9°C, Slight orange tinge, 90% transparent	0-53m = backfill	
60	Basal Crete		Calcrete: Yellow-brown angular siliceous goethite with silcrete/calcrete infill & blue-grey vitreous goethite, minor white calcrete.			EC: 16500uS/cm, pH: 7.96, Temp: 30.2°C, Slight white cloudiness, 90% transparent	100mm CL18 PVC Blank Casing	
70	West Angela		Hardcap: Dark blue-grey angular goethite dark brown streak, yellow-brown goethite with cystalline infill 66-68m, vuggy goethite chips with <1mm nodular concretions on surfaces, minor yellow limonitic goethite, increasing to 40% 68-70m, 74-76m. From 80m, yellow goethite (some limonitic goethite clayey when wet) content increasing to 50%.			EC: 17100uS/cm, pH: 7.82, Temp: 32.5°C, Slight white cloudiness, 90% transparent		
80						EC: 16700uS/cm, pH: 8, Temp: 28.3°C, Slight yellow tinge, 90% transparent	53-94m = bentonite/grout seal	
90			Hardcap: Mineralised goethite blue-grey, dark brown streak, minor red-purple shale soft.			EC: 17500uS/cm, pH: 7.85, Temp: 31.1°C, Slight yellow tinge, 90% transparent		
100			Shale: Grey massive shale/clay moderate plasticity, minor red shale and yellow goethite.			EC: 17600uS/cm, pH: 7.85, Temp: 30.3°C, Light khaki, slightly transparent	94-96m = bentonite seal	
110			Dolomite: Transition zone 92-94m, crystalline blue-grey/white dolomite thin and fizzes with HCl, also crystalline quartz infill. Very slow drilling penetration rate.			EC: 17500uS/cm, pH: 7.91, Temp: 31°C, Light yellow tinge, transparent	2-130m = gravel pack (3.2-6.4mm)	
120			Dolomite: Dark blue-grey-green dolomite, highly weathered, thin fissile.			EC: 17200uS/cm, pH: 7.87, Temp: 29.9°C, Light grey tinge	96-118.5m = gravel pack (3.2-6.4mm)	
130			BIF: Dark blue-grey soft hematitic shale, yellow goethitic shale (increased 104-110m), also dark brown to blue-grey, yellow BIF interbedded with chert, some crystalline infill, grey/white clay. No sample 118-120m.			EC: 17900uS/cm, pH: 7.8, Temp: 29.7°C, Light yellow tinge, 50% transparency. Switched to OH.	100.5-118.5m = 100mm CL18 PVC Slotted Casing, 1mm aperture	
						EC: 18200uS/cm, pH: 7.81, Temp: 28.6°C, Yellow-brown tint, cloudy opaque.		
						EC: 18900uS/cm, pH: 7.8, Temp: 30.6°C, Khaki-brown, opaque. V-notch blew out.		
						No water sample taken.		

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COMPOSITE WELL LOG

Bore No: MDPZ9212S

Client: Roy Hill

Project: Mulga Downs PFS Investigation

Commenced: 654386
Completed: 7546688
Drilled: Pentium Hydro
Logged By: AS

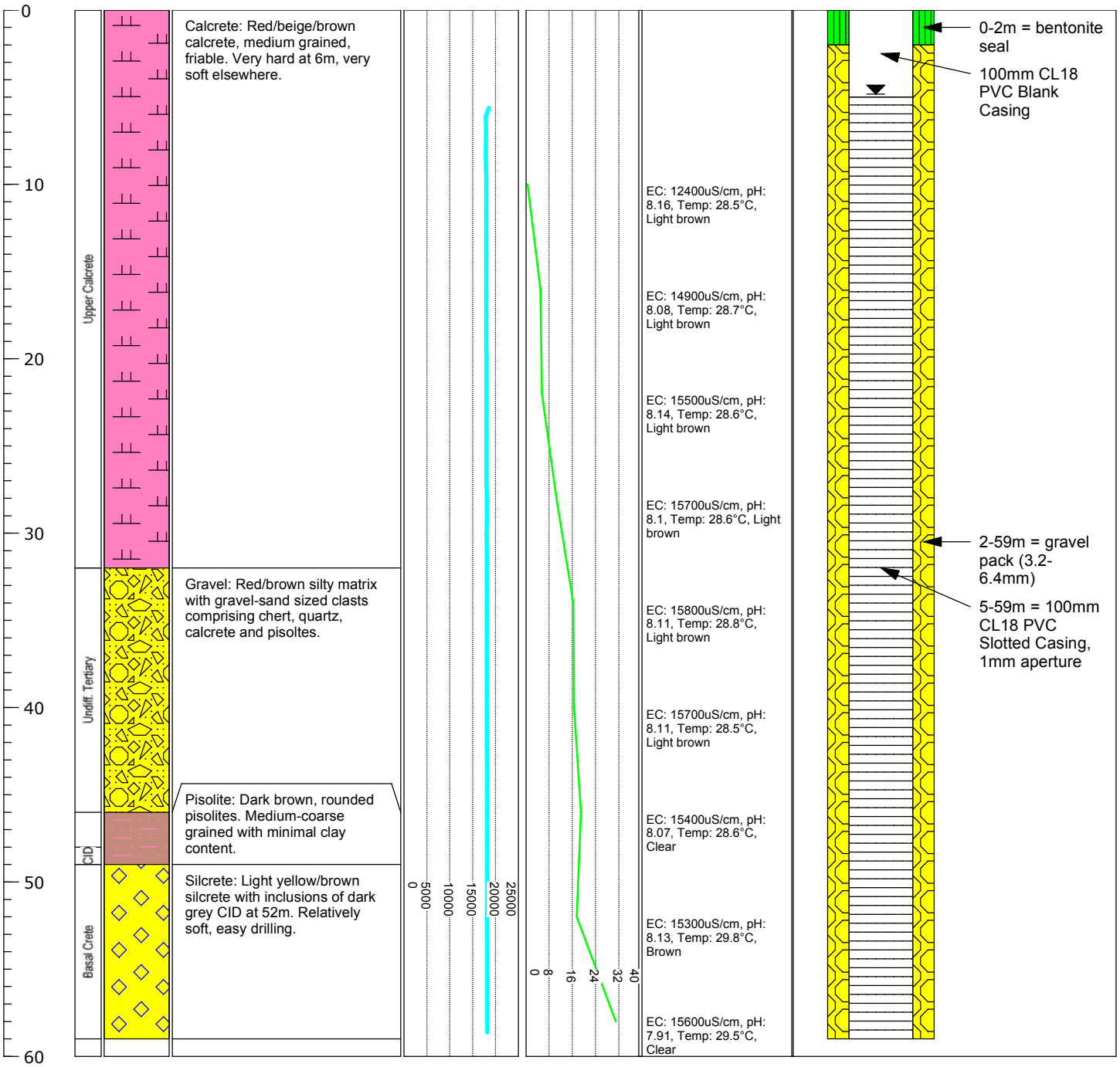
Method: DR
Fluid: Air
Bit Record: 0-59m = 230mm

Area: Malay Well
GL Elevation: 404.95 mAHD
Easting: 654386
Northing: 7546690
Projection: MGA94 Zone 50

Static Water Level: 5.22 mbtoc
Date: 5/11/2021

Remarks: Stick up = 0.40m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Drilling Yield (L/s)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0 – 30	Upper Calcrete		Calcrete: Red/beige/brown calcrete, medium grained, friable. Very hard at 6m, very soft elsewhere.			EC: 12400uS/cm, pH: 8.16, Temp: 28.5°C, Light brown EC: 14900uS/cm, pH: 8.08, Temp: 28.7°C, Light brown EC: 15500uS/cm, pH: 8.14, Temp: 28.6°C, Light brown EC: 15700uS/cm, pH: 8.1, Temp: 28.6°C, Light brown	0-2m = bentonite seal 100mm CL18 PVC Blank Casing	
30 – 40	Undiff Tertiary		Gravel: Red/brown silty matrix with gravel-sand sized clasts comprising chert, quartz, calcrete and pisoltes.			EC: 15800uS/cm, pH: 8.11, Temp: 28.8°C, Light brown EC: 15700uS/cm, pH: 8.11, Temp: 28.5°C, Light brown	2-59m = gravel pack (3.2-6.4mm) 5-59m = 100mm CL18 PVC Slotted Casing, 1mm aperture	
40 – 50	CID		Pisolite: Dark brown, rounded pisolites. Medium-coarse grained with minimal clay content.			EC: 15400uS/cm, pH: 8.07, Temp: 28.6°C, Clear		
50 – 60	Basal Crete		Silcrete: Light yellow/brown silcrete with inclusions of dark grey CID at 52m. Relatively soft, easy drilling.			EC: 15300uS/cm, pH: 8.13, Temp: 29.8°C, Brown EC: 15600uS/cm, pH: 7.91, Temp: 29.5°C, Clear		



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COMPOSITE WELL LOG

Bore No: MDPZ9213

Client: Roy Hill

Project: Mulga Downs PFS Investigation

Commenced: 26/09/2021
Completed: 01/10/2021
Drilled: Pentium Hydro
Logged By: CS

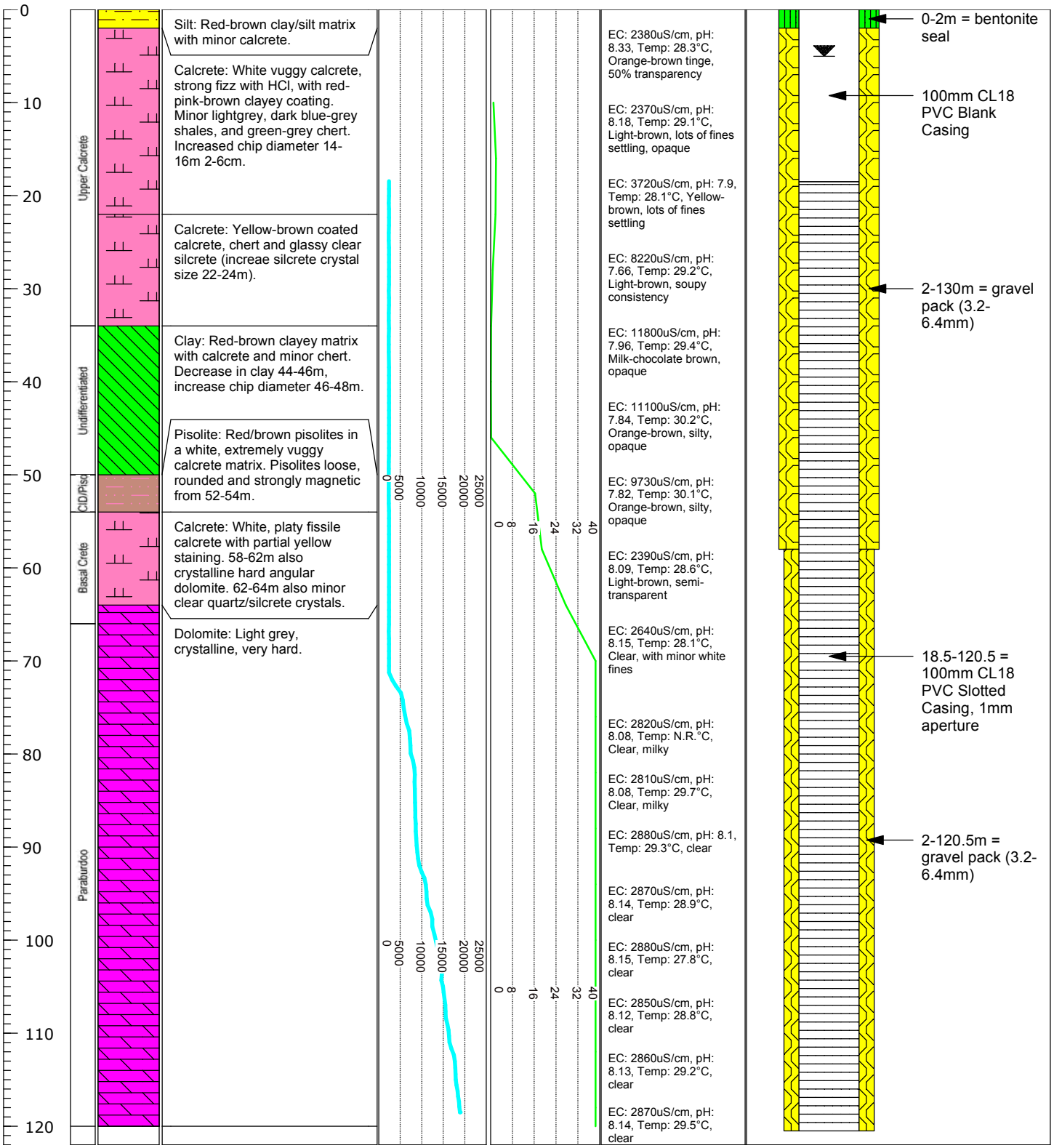
Method: DR / DTH
Fluid: Air
Bit Record: 0-58m = 230mm
58-120m = 190mm

Area: Malay Well
GL Elevation: 404.53 mAHD
Easting: 649610
Northing: 7544612
Projection: MGA94 Zone 50

Static Water Level: 4.99 mbtoc
Date: 6/10/2021

Remarks: Stick up = 0.40m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Drilling Yield (L/s)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0	Upper Calcrete		Silt: Red-brown clay/silt matrix with minor calcrete.			EC: 2380uS/cm, pH: 8.33, Temp: 28.3°C, Orange-brown tinge, 50% transparency		0-2m = bentonite seal
10	Upper Calcrete		Calcrete: White vuggy calcrete, strong fizz with HCl, with red-pink-brown clayey coating. Minor lightgrey, dark blue-grey shales, and green-grey chert. Increased chip diameter 14-16m 2-6cm.			EC: 2370uS/cm, pH: 8.18, Temp: 29.1°C, Light-brown, lots of fines settling, opaque		100mm CL18 PVC Blank Casing
20	Upper Calcrete					EC: 3720uS/cm, pH: 7.9, Temp: 28.1°C, Yellow-brown, lots of fines settling		
30	Upper Calcrete		Calcrete: Yellow-brown coated calcrete, chert and glassy clear silcrete (increae silcrete crystal size 22-24m).			EC: 8220uS/cm, pH: 7.66, Temp: 29.2°C, Light-brown, soupy consistency		2-130m = gravel pack (3.2-6.4mm)
40	Undifferentiated		Clay: Red-brown clayey matrix with calcrete and minor chert. Decrease in clay 44-46m, increase chip diameter 46-48m.			EC: 11800uS/cm, pH: 7.96, Temp: 29.4°C, Milk-chocolate brown, opaque		
50	CID/Piso		Pisolite: Red/brown pisolites in a white, extremely vuggy calcrete matrix. Pisolites loose, rounded and strongly magnetic from 52-54m.			EC: 11100uS/cm, pH: 7.84, Temp: 30.2°C, Orange-brown, silty, opaque		
60	Basal Crete		Calcrete: White, platy fissile calcrete with partial yellow staining. 58-62m also crystalline hard angular dolomite. 62-64m also minor clear quartz/silcrete crystals.			EC: 9730uS/cm, pH: 7.82, Temp: 30.1°C, Orange-brown, silty, opaque		
70	Paraburdoo		Dolomite: Light grey, crystalline, very hard.			EC: 2390uS/cm, pH: 8.09, Temp: 28.6°C, Light-brown, semi-transparent		18.5-120.5 = 100mm CL18 PVC Slotted Casing, 1mm aperture
80	Paraburdoo					EC: 2640uS/cm, pH: 8.15, Temp: 28.1°C, Clear, with minor white fines		
90	Paraburdoo					EC: 2820uS/cm, pH: 8.08, Temp: N.R.°C, Clear, milky		
100	Paraburdoo					EC: 2810uS/cm, pH: 8.08, Temp: 29.7°C, Clear, milky		
110	Paraburdoo					EC: 2880uS/cm, pH: 8.1, Temp: 29.3°C, clear		2-120.5m = gravel pack (3.2-6.4mm)
120	Paraburdoo					EC: 2870uS/cm, pH: 8.14, Temp: 28.9°C, clear		
						EC: 2880uS/cm, pH: 8.15, Temp: 27.8°C, clear		
						EC: 2850uS/cm, pH: 8.12, Temp: 28.8°C, clear		
						EC: 2860uS/cm, pH: 8.13, Temp: 29.2°C, clear		
						EC: 2870uS/cm, pH: 8.14, Temp: 29.5°C, clear		



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COMPOSITE WELL LOG

Bore No: MDPZ9214

Client: Roy Hill

Project: Mulga Downs PFS Investigation

Commenced: 03/10/2021
Completed: 10/10/2021
Drilled: Pentium Hydro
Logged By: AS

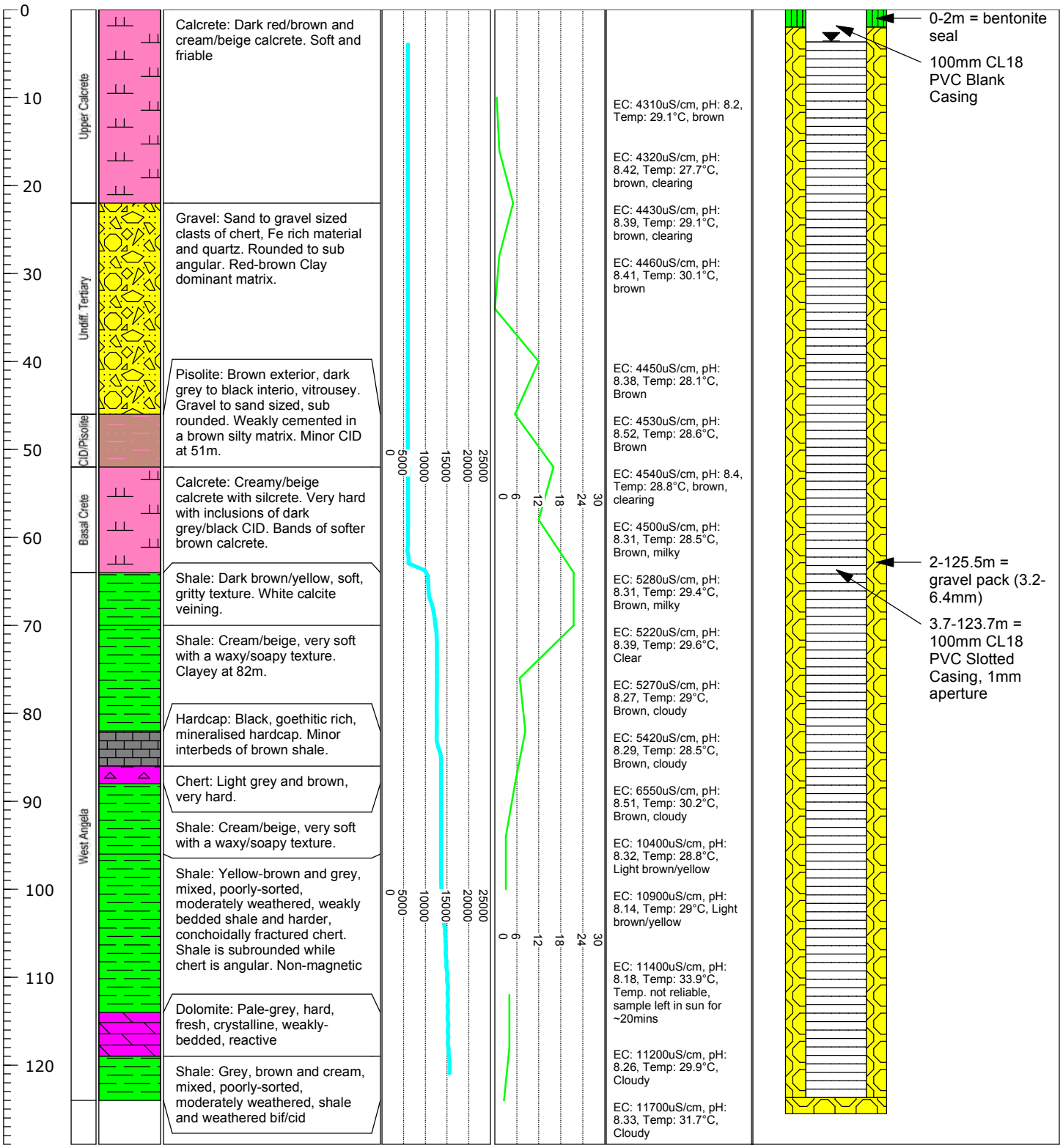
Method: DR
Fluid: Air
Bit Record: 0-126.5m = 230mm

Area: Malay Well
GL Elevation: 403.02 mAHD
Easting: 647989
Northing: 7547414
Projection: MGA94 Zone 50

Static Water Level: 4.03 mbtoc
Date: 12/10/2021

Remarks: Stick up = 0.45m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Drilling Yield (L/s)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0–20	Upper Calcrete		Calcrete: Dark red/brown and cream/beige calcrete. Soft and friable			EC: 4310uS/cm, pH: 8.2, Temp: 29.1°C, brown	0-2m = bentonite seal	100mm CL18 PVC Blank Casing
20–30	Undiff. Tertiary		Gravel: Sand to gravel sized clasts of chert, Fe rich material and quartz. Rounded to sub angular. Red-brown Clay dominant matrix.			EC: 4320uS/cm, pH: 8.42, Temp: 27.7°C, brown, clearing EC: 4430uS/cm, pH: 8.39, Temp: 29.1°C, brown, clearing EC: 4460uS/cm, pH: 8.41, Temp: 30.1°C, brown		
30–40	Undiff. Tertiary		Pisolite: Brown exterior, dark grey to black interio, vitrousey. Gravel to sand sized, sub rounded. Weakly cemented in a brown silty matrix. Minor CID at 51m.			EC: 4450uS/cm, pH: 8.38, Temp: 28.1°C, Brown EC: 4530uS/cm, pH: 8.52, Temp: 28.6°C, Brown		
40–50	CID/Pisolite							
50–60	Basal Crete		Calcrete: Creamy/beige calcrete with silcrete. Very hard with inclusions of dark grey/black CID. Bands of softer brown calcrete.			EC: 4540uS/cm, pH: 8.4, Temp: 28.8°C, brown, clearing EC: 4500uS/cm, pH: 8.31, Temp: 28.5°C, Brown, milky		
60–70	West Angela		Shale: Dark brown/yellow, soft, gritty texture. White calcite veining.			EC: 5280uS/cm, pH: 8.31, Temp: 29.4°C, Brown, milky		
70–80	West Angela		Shale: Cream/beige, very soft with a waxy/soapy texture. Clayey at 82m.			EC: 5220uS/cm, pH: 8.39, Temp: 29.6°C, Clear EC: 5270uS/cm, pH: 8.27, Temp: 29°C, Brown, cloudy		
80–90	West Angela		Hardcap: Black, goethitic rich, mineralised hardcap. Minor interbeds of brown shale.			EC: 5420uS/cm, pH: 8.29, Temp: 28.5°C, Brown, cloudy		
90–100	West Angela		Chert: Light grey and brown, very hard. Shale: Cream/beige, very soft with a waxy/soapy texture.			EC: 6550uS/cm, pH: 8.51, Temp: 30.2°C, Brown, cloudy		
100–110	West Angela		Shale: Yellow-brown and grey, mixed, poorly-sorted, moderately weathered, weakly bedded shale and harder, conchoidally fractured chert. Shale is subrounded while chert is angular. Non-magnetic			EC: 10400uS/cm, pH: 8.32, Temp: 28.8°C, Light brown/yellow EC: 10900uS/cm, pH: 8.14, Temp: 29°C, Light brown/yellow	2-125.5m = gravel pack (3.2-6.4mm) 3.7-123.7m = 100mm CL18 PVC Slotted Casing, 1mm aperture	
110–120	West Angela		Dolomite: Pale-grey, hard, fresh, crystalline, weakly-bedded, reactive			EC: 11400uS/cm, pH: 8.18, Temp: 33.9°C, Temp. not reliable, sample left in sun for ~20mins		
120–	West Angela		Shale: Grey, brown and cream, mixed, poorly-sorted, moderately weathered, shale and weathered bif/cid			EC: 11200uS/cm, pH: 8.26, Temp: 29.9°C, Cloudy EC: 11700uS/cm, pH: 8.33, Temp: 31.7°C, Cloudy		



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COMPOSITE WELL LOG

Bore No: MDPZ9215D

Client: Roy Hill

Project: Mulga Downs PFS Investigation

Commenced: 643991
Completed: 7550204
Drilled: Pentium Hydro
Logged By: AS

Method: DR
Fluid: Air
Bit Record: 0-130m = 230mm

Area: Malay Well
GL Elevation: 403.21mAHD
Easting: 643992
Northing: 7550206
Projection: MGA94 Zone 50

Static Water Level: 4.74 mbtoc
Date: 17/10/2021

Remarks: Stick up = 0.38m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Drilling Yield (L/s)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0	Alluv		Clay: Brown, fine- to coarse-grained, silts and gravels (mainly calcrete). Poorly sorted, mixed, subangular			EC: 9820uS/cm, pH: 7.87, Temp: 29.3°C, 4m Rod. Cloudy	0-25m = backfill	
10	Upper Calcrete		Calcrete: Brown and cream to light green-yellow, cemented, friable, medium-grained calcrete. Reacts strongly to HCl			EC: 10400uS/cm, pH: 8.08, Temp: 28.3°C, Brown		
20			Clay: Red-brown, fine- to coarse-grained, poorly-sorted, subrounded. Mainly clay with gravels (calcrete and quartz) and minor pisolites			EC: 3250uS/cm, pH: 8.31, Temp: 28.5°C, Light brown		
30	Undiff. Tertiary		Clay: Red-brown, soft, sticky, plastic subrounded clay with minor coarse clastics (mainly calcrete)			EC: 5080uS/cm, pH: 8.22, Temp: 29.9°C, Dark brown		
40			Gravel: Red-brown, gravel and clay. Gravel is subrounded, mixed and poorly-sorted. Clay (~20%) is silty			EC: 7060uS/cm, pH: 8.07, Temp: 31.1°C, Dark brown, muddy	100mm CL18 PVC Blank Casing	
50	Basal Crete		Calcrete: White, cemented, vuggy, subangular and very hard. Silcrete dominant from 62m			EC: 9900uS/cm, pH: 8.09, Temp: 30.7°C, Dark red-brown, muddy		
60						EC: 9510uS/cm, pH: 8.07, Temp: 30.8°C, Dark red-brown, muddy	25-65.5m = bentonite/grout seal	
70	West Angela		Hardcap: Dark grey/black with a metalic lustre, vuggy. Minor brown clay.			EC: 8650uS/cm, pH: 8.1, Temp: 30.9°C, Red-brown, muddy		
80			Shale: White/beige with a soapy/waxy texture. Puggy clay at 80m.			EC: 3880uS/cm, pH: 8.46, Temp: 30.7°C, Light-brown, cloudy		
90			BIF: Dark red/brown/grey BIF with light light brown/beige shale.			EC: 3650uS/cm, pH: 8.33, Temp: 28.7°C, Clear, getting harder		
100			Chert: Dark grey chert and yellow/brown shale.			EC: 5090uS/cm, pH: 8.23, Temp: 29°C, Clear	61.5-64m = bentonite seal	
110						EC: 5860uS/cm, pH: 8.06, Temp: 30.2°C, Clear		
120			BIF: Dark brown/yellow, goethite dominant. Interbeds of chert and shale.			EC: 6370uS/cm, pH: 8.2, Temp: 29.7°C, Light brown/cloudy		
130			Chert: Dark grey, very hard			EC: 7150uS/cm, pH: 8.2, Temp: 28.5°C, Light brown/cloudy	64-130m = gravel pack (3.2-6.4mm)	
			Shale: Brown, soft with minor goethite chips.			EC: 7460uS/cm, pH: 8.18, Temp: 28.9°C, Dirty grey/brown	70-130m = 100mm CL18 PVC Slotted Casing, 1mm aperture	
						EC: 7250uS/cm, pH: 8.21, Temp: 30°C, Light brown		
						EC: 6980uS/cm, pH: 8.23, Temp: 29.1°C, brown/yellow		
						EC: 12800uS/cm, pH: 7.93, Temp: 28.2°C, brown/yellow		
						EC: 12700uS/cm, pH: 7.95, Temp: 30.1°C, dark yellow		
						EC: 16100uS/cm, pH: 7.85, Temp: 29.4°C, light yellow		
						EC: 23000uS/cm, pH: 7.77, Temp: 30.9°C, clear		
						EC: 23300uS/cm, pH: 7.78, Temp: 30.2°C, clear		

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COMPOSITE WELL LOG

Bore No: MDPZ9215S

Client: Roy Hil

Project: Mulga Downs PFS Investigation

Commenced: 26/10/2021
Completed: 27/10/2021
Drilled: Pentium Hydro
Logged By: CS

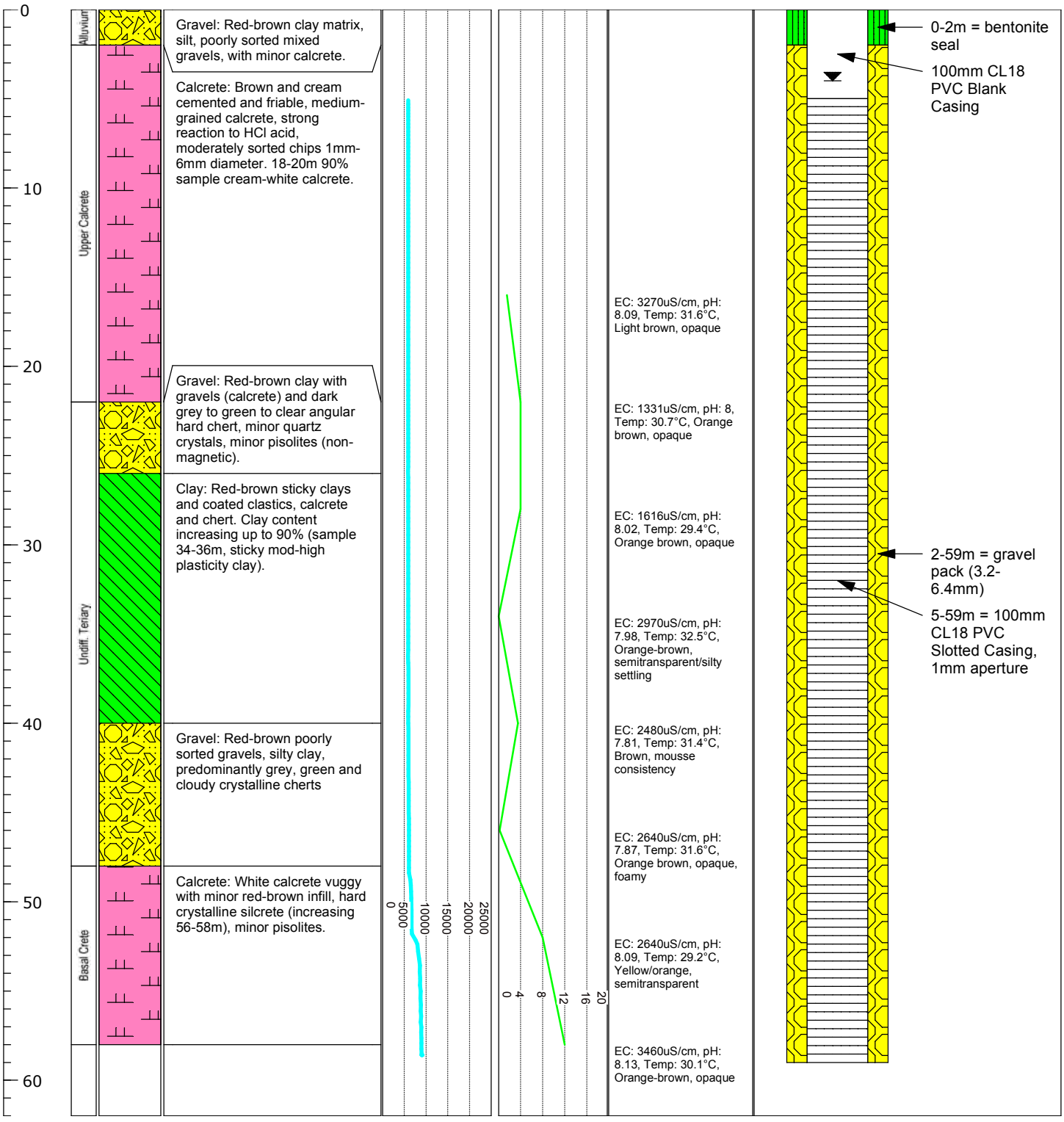
Method: DR
Fluid: Air
Bit Record: 0-59m = 230mm

Area: Malay Well
GL Elevation: 403.14 mAHD
Easting: 643992
Northing: 7550192
Projection: MGA94 Zone 50

Static Water Level: 4.47 mbtoc
Date: 29/10/2021

Remarks: Stick up = 0.47m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Drilling Yield (L/s)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0–60	Alluvium / Upper Calcrete / Undiff. Teriary / Basal Crete		Gravel: Red-brown clay matrix, silt, poorly sorted mixed gravels, with minor calcrete.			EC: 3270uS/cm, pH: 8.09, Temp: 31.6°C, Light brown, opaque	0-2m = bentonite seal	
			Calcrete: Brown and cream cemented and friable, medium-grained calcrete, strong reaction to HCl acid, moderately sorted chips 1mm-6mm diameter. 18-20m 90% sample cream-white calcrete.			EC: 1331uS/cm, pH: 8, Temp: 30.7°C, Orange brown, opaque	100mm CL18 PVC Blank Casing	
			Gravel: Red-brown clay with gravels (calcrete) and dark grey to green to clear angular hard chert, minor quartz crystals, minor pisolites (non-magnetic).			EC: 1616uS/cm, pH: 8.02, Temp: 29.4°C, Orange brown, opaque		
			Clay: Red-brown sticky clays and coated clastics, calcrete and chert. Clay content increasing up to 90% (sample 34-36m, sticky mod-high plasticity clay).			EC: 2970uS/cm, pH: 7.98, Temp: 32.5°C, Orange-brown, semitransparent/silty settling	2-59m = gravel pack (3.2-6.4mm)	
			Gravel: Red-brown poorly sorted gravels, silty clay, predominantly grey, green and cloudy crystalline cherts			EC: 2480uS/cm, pH: 7.81, Temp: 31.4°C, Brown, mousse consistency	5-59m = 100mm CL18 PVC Slotted Casing, 1mm aperture	
			Calcrete: White calcrete vuggy with minor red-brown infill, hard crystalline silcrete (increasing 56-58m), minor pisolites.			EC: 2640uS/cm, pH: 7.87, Temp: 31.6°C, Orange brown, opaque, foamy		
						EC: 2640uS/cm, pH: 8.09, Temp: 29.2°C, Yellow/orange, semitransparent		
						EC: 3460uS/cm, pH: 8.13, Temp: 30.1°C, Orange-brown, opaque		



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COMPOSITE WELL LOG

Bore No: MDPZ9216

Client: Roy Hill

Project: Mulga Downs PFS Investigation

Commenced: 19/10/2021
Completed: 24/10/2021
Drilled: Pentium Hydro
Logged By: CS

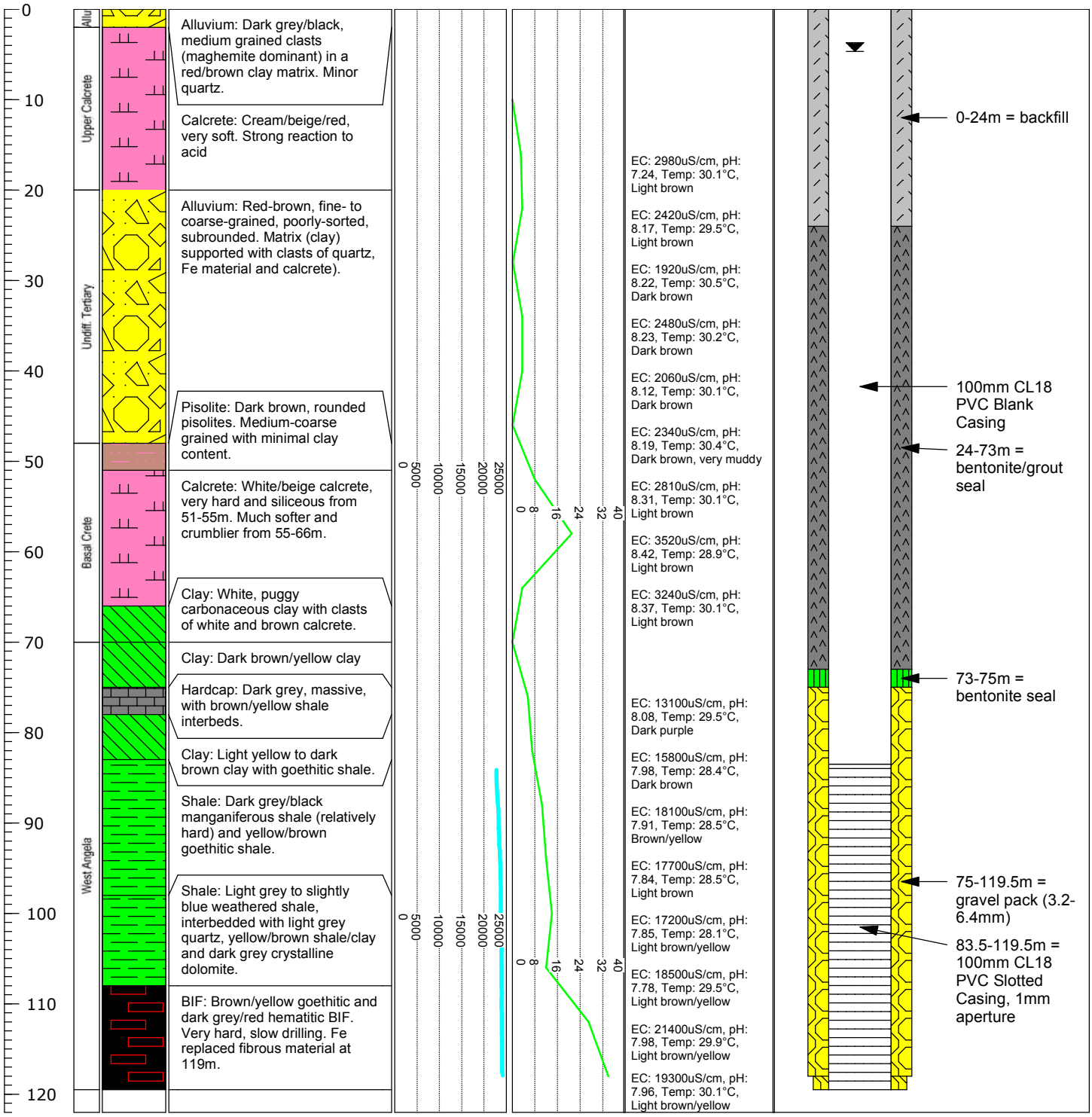
Method: DR / DTH
Fluid: Air
Bit Record: 0-118m = 230mm
118-119.5m = 190mm

Area: Malay Well
GL Elevation: 403.24 mAHD
Easting: 643199
Northing: 7551012
Projection: MGA94 Zone 50

Static Water Level: 5.10 mbtoc
Date: 2/11/2021

Remarks: Stick up = 0.42m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Drilling Yield (L/s)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0	Allu		Alluvium: Dark grey/black, medium grained clasts (maghemite dominant) in a red/brown clay matrix. Minor quartz.			EC: 2980uS/cm, pH: 7.24, Temp: 30.1°C, Light brown	0-24m = backfill	
10	Upper Calcrete		Calcrete: Cream/beige/red, very soft. Strong reaction to acid			EC: 2420uS/cm, pH: 8.17, Temp: 29.5°C, Light brown		
20	Undiff. Tertiary		Alluvium: Red-brown, fine- to coarse-grained, poorly-sorted, subrounded. Matrix (clay) supported with clasts of quartz, Fe material and calcrete).			EC: 1920uS/cm, pH: 8.22, Temp: 30.5°C, Dark brown		
30						EC: 2480uS/cm, pH: 8.23, Temp: 30.2°C, Dark brown		
40						EC: 2060uS/cm, pH: 8.12, Temp: 30.1°C, Dark brown	100mm CL18 PVC Blank Casing	
50			Pisolite: Dark brown, rounded pisolites. Medium-coarse grained with minimal clay content.			EC: 2340uS/cm, pH: 8.19, Temp: 30.4°C, Dark brown, very muddy	24-73m = bentonite/grout seal	
60	Basal Crete		Calcrete: White/beige calcrete, very hard and siliceous from 51-55m. Much softer and crumblier from 55-66m.			EC: 2810uS/cm, pH: 8.31, Temp: 30.1°C, Light brown		
70			Clay: White, puggy carbonaceous clay with clasts of white and brown calcrete.			EC: 3520uS/cm, pH: 8.42, Temp: 28.9°C, Light brown		
80			Clay: Dark brown/yellow clay			EC: 3240uS/cm, pH: 8.37, Temp: 30.1°C, Light brown	73-75m = bentonite seal	
90	West Angela		Hardcap: Dark grey, massive, with brown/yellow shale interbeds.			EC: 13100uS/cm, pH: 8.08, Temp: 29.5°C, Dark purple		
100			Clay: Light yellow to dark brown clay with goethitic shale.			EC: 15800uS/cm, pH: 7.98, Temp: 28.4°C, Dark brown		
110			Shale: Dark grey/black manganiferous shale (relatively hard) and yellow/brown goethitic shale.			EC: 18100uS/cm, pH: 7.91, Temp: 28.5°C, Brown/yellow		
120			Shale: Light grey to slightly blue weathered shale, interbedded with light grey quartz, yellow/brown shale/clay and dark grey crystalline dolomite.			EC: 17700uS/cm, pH: 7.84, Temp: 28.5°C, Light brown	75-119.5m = gravel pack (3.2-6.4mm)	
			BIF: Brown/yellow goethitic and dark grey/red hematitic BIF. Very hard, slow drilling. Fe replaced fibrous material at 119m.			EC: 17200uS/cm, pH: 7.85, Temp: 28.1°C, Light brown/yellow	83.5-119.5m = 100mm CL18 PVC Slotted Casing, 1mm aperture	
						EC: 18500uS/cm, pH: 7.78, Temp: 29.5°C, Light brown/yellow		
						EC: 21400uS/cm, pH: 7.98, Temp: 29.9°C, Light brown/yellow		
						EC: 19300uS/cm, pH: 7.96, Temp: 30.1°C, Light brown/yellow		



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COMPOSITE WELL LOG

Bore No: MDPZ9217

Client: Roy Hill

Project: Mulga Downs PFS Investigation

Commenced: 18/11/2021
Completed: 20/22/2021
Drilled: Pentium Hydro
Logged By: CS

Method: DR / DTH
Fluid: Air
Bit Record: 0-58m = 230mm
58-88m = 190mm

Area: Mulga West
GL Elevation: 402.09 mAHD
Easting: 632854
Northing: 7556252
Projection: MGA94 Zone 50

Static Water Level: 4.78 mbtoc
Date: 21/11/2021

Remarks: Stick up = 0.42m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Drilling Yield (L/s)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0 – 90	Alluvium / Undiff Tertiary / CID Pisolite / Marra Mamba		Clay: Red/brown, silty, sandy, gravelly clay. Clay: Pale grey/brown mottled calcareaous clay with silty sand chips. Gravelly Clay: Red/brown, silty, sandy, gravelly clay (40-60% clay). Rounded to subangular, ~1cm fragments. Gravel: Red/brown sandy gravel, rounded to subangular, fragments upto 2cm (size increasing). Pisolite: Red/brown pisolitic gravel (loose), few large fragments (~3cm), becoming increasingly well sorted at depth. CID: Cemented pisolitic gravel. Chert: Weathered fragments upto 4-5cm with weathered surfaces comprising BIF, Chert and Shale. Shale: Light pink shale with light grey chert. 3-4cm fragments. Shale: As above but shale is yellow. 3-4cm fragments. Chert: Grey chert with a pink tinge with light pink shale. Shale: Predominantley white and grey shale with light grey and dark grey chert (3-4cm chip size). BIF: Dark grey BIF (magnetic) with interbeds of shale and chert (brown). Angular chips generally >2cm. Shale: Light green shale with light grey/blue chert. Shale: Black shale, very soft and clayey Chert: Dark grey chert with black and white shale.	0 5000 10000 15000 20000 25000	0 8 16 24 32 40	EC:-uS/cm, pH:-, Temp:-°C, EC:-uS/cm, pH:-, Temp:-°C, Sludge EC:9000uS/cm, pH:7.29, Temp:32.1°C, EC:8260uS/cm, pH:7.32, Temp:32.1°C, EC:8490uS/cm, pH:7.4, Temp:30.5°C, EC:8100uS/cm, pH:7.3, Temp:33°C, EC:7910uS/cm, pH:7.47, Temp:34.8°C, EC:8330uS/cm, pH:7.37, Temp:31°C, EC:8210uS/cm, pH:7.56, Temp:31.8°C, Switch to OH from 58m EC:8270uS/cm, pH:7.4, Temp:32.1°C, EC:8750uS/cm, pH:7.92, Temp:-°C, Sample left in sun- no Temp EC:10500uS/cm, pH:7.85, Temp:-°C, Sample left in sun- no Temp EC:11100uS/cm, pH:7.86, Temp:-°C, Sample left in sun- no Temp EC:11200uS/cm, pH:7.87, Temp:32.3°C, EC:11200uS/cm, pH7.87, Temp32.3°C,	0-2m = bentonite/grout seal 100mm CL18 PVC Blank Casing 2-89m = gravel pack (3.2-6.4mm) 5-89m = 100mm CL18 PVC Slotted Casing, 1mm aperture	

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COMPOSITE WELL LOG

Bore No: MDPZ9218

Client: Roy Hill

Project: Mulga Downs PFS Investigation

Commenced: 21/11/2021
Completed: 26/11/2021
Drilled: Pentium Hydro
Logged By: CS

Method: DR / DTH
Fluid: Air
Bit Record: 0-82m = 230mm
82-92m = 190mm

Area: Mulga West
GL Elevation: 398.85mAHD
Easting: 622035
Northing: 7555800
Projection: MGA94 Zone 50

Static Water Level: 3.43 mbtoc
Date: 12/12/2021

Remarks: Stick up = 0.40m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Drilling Yield (L/s)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0 – 90	Alluvium; Upper Calcrete; Undiff. Tertiary; CID Pisolite; Basal Crete; West Angela; Marra Mamba		Alluvium: Red clay with ~1mm clasts of rounded chert and pisolitic gravel. Calcrete: Light pink/brown/beige calcrete Clay: Light brown-red clasts calcrete (angular, ~15mm) with clasts of chert (~1mm) in a light brown clay matrix. Clay: Dark grey, angular clasts of chert, typically >1mm. Minor quartz and pisolitic gravel in red clayey matrix. Gravel: Chert, pisolitic gravel and quartz with minimal red clay content. Pisolite: Red/brown exterior, dark grey/black interior. Fine to coarse grained (1-20mm), subrounded, poorly sorted. Calcrete: Cream/beige calcrete with inclusions of dark grey/black CID/Pisolite. Soft, easy drilling. Shale: Light brown/yellow clasts of goethtic shale with softer white shale/clay. Chert: Brown/dark grey chert with yellow and beige shale. BIF: Dark grey BIF (magnetite dominant) with light grey chert and dark grey shale. Chert: Yellow, grey and brown chert with dark grey/black BIF.	0, 2000, 4000, 6000, 8000, 10000	0, 6, 12, 18, 24, 30	EC: 6990 uS/cm, pH: 8.16, T= 29.60°C EC: 6310 uS/cm, pH: 8.10, T= 29.30°C EC: 5210 uS/cm, pH: 8.15, T= 29.60°C EC: 5390 uS/cm, pH: 8.10, T= 29.50°C EC: 6850 uS/cm, pH: 8.10, T= 31.10°C EC: 6910 uS/cm, pH: 7.94, T= 30.7°C EC: 6900 uS/cm, pH: 8.02, T= 30.80°C EC: 7490 uS/cm, pH: 8.08, T= 31.10°C EC: 8090 uS/cm, pH: 7.86, T= 30.10°C	0-2m = bentonite/grout seal 100mm CL18 PVC Blank Casing 2-92m = gravel pack (3.2-6.4mm) 8-92m = 100mm CL18 PVC Slotted Casing, 1mm apertyre	

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COMPOSITE WELL LOG

Bore No: MDPZ9219

Client: Roy Hill

Project: Mulga Downs PFS Investigation

Commenced: 27/11/2021
Completed: 30/11/2021
Drilled: Pentium Hydro
Logged By: CS

Method: DR / DTH
Fluid: Air
Bit Record: 0-100m = 230mm
100-112m = 190mm

Area: Mulga West
GL Elevation: 396.82 mAHD
Easting: 618440
Northing: 7555798
Projection: MGA94 Zone 50

Static Water Level: 3.69 mbtoc
Date: 5/12/2021

Remarks: Stick up = 0.46m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Drilling Yield (L/s)	Field Notes	Well Completion Diagram	Well Completion Notes
0	Alluvium		Clay: Red clay with silt and gravel	EC:6180uS/cm, pH:8.01, Temp:31.9°C,			0-2m = bentonite/grout seal	
10	Upper Calcrete		Calcrete: White/beige, very soft	EC:5800uS/cm, pH:8.04, Temp:31.8°C,			100mm CL18 PVC Blank Casing	
20				EC:5540uS/cm, pH:8.1, Temp:31.9°C,				
30			Clay: Light brown claywith clasts of calcrete and rounded chert	EC:4150uS/cm, pH:8.11, Temp:29.9°C,				
40	Undiff. Tertiary		Alluvium: Clasts of chert (~2cm) with minor silt and clay	EC:3750uS/cm, pH:7.96, Temp:30.7°C,				
50	CID Pisolite		Pisolite: Red/brown pisolites, poorly sorted, subrounded with minor clay and CID	EC:3730uS/cm, pH:8.08, Temp:30.4°C,			2-112m = gravel pack (3.2-6.4mm)	
			Clay: Light brown clay with dark brown CID	EC:4020uS/cm, pH:8.01, Temp:29.9°C,				
60	Basal Crete		Calcrete: white calcrete, gradational boundary between CID until 58m.	EC:4020uS/cm, pH:8.01, Temp:29°C,			10-112 = 100mm CL18 PVC Slotted Casing, 1mm aperture	
70			Hardcap: Dark grey/black manganiferous hardcap with light brown/yellow goethitic shale.	EC:4870uS/cm, pH:7.93, Temp:30.8°C,				
80			Chert: light brown chert with white, soapy shale.	EC:4390uS/cm, pH:8.14, Temp:30.9°C,				
			Chert: Pink, very fractured chert (6-8cm chip sizes)	EC:5440uS/cm, pH:8.12, Temp:30.6°C,				
90	Marra Mamba		Chert: Light grey chert with white shale (3-4cm chip size)	EC:4140uS/cm, pH:8.17, Temp:29.4°C,				
				EC:4050uS/cm, pH:8.15, Temp:29.4°C,				
100			Chert: Dark grey/brown chert and BIF (magnetite)	EC:3960uS/cm, pH:8.03, Temp:28.9°C,				
				EC:4070uS/cm, pH:8.01, Temp:28.9°C,				
				EC:4130uS/cm, pH:8.04, Temp:30.4°C,				
				EC:4140uS/cm, pH:8.15, Temp:29.9°C,				
110				EC:4210uS/cm, pH:8.13, Temp:30.3°C,				
				EC:4170uS/cm, pH:8.21, Temp:30.3°C,				

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COMPOSITE WELL LOG

Bore No: MDPZ9220

Client: Roy Hill

Project: Mulga Downs PFS Investigation

Commenced: 3/12/2021
Completed: 6/12/2021
Drilled: Pentium Hydro
Logged By: CS

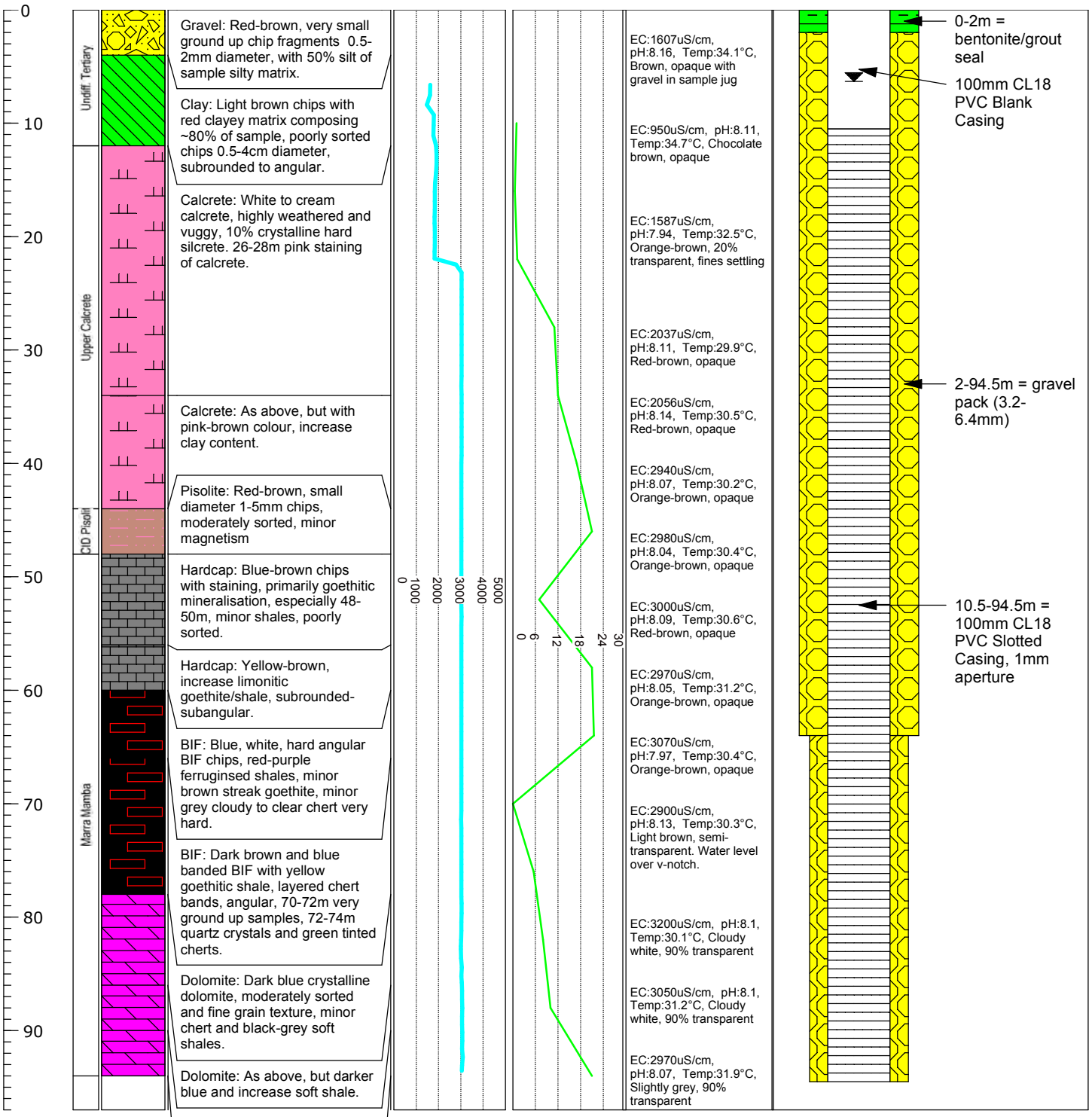
Method: DR / DTH
Fluid: Air
Bit Record: 0-64m = 230mm
64-94m = 190mm

Area: Mulga West
GL Elevation: 394.98 mAHD
Easting: 610046
Northing: 7558820
Projection: MGA94 Zone 50

Static Water Level: 6.32 mbtoc
Date: 12/12/2021

Remarks: Stick up = 0.37m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Drilling Yield (L/s)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0	Undiff. Tertiary		Gravel: Red-brown, very small ground up chip fragments 0.5-2mm diameter, with 50% silt of sample silty matrix.			EC:1607uS/cm, pH:8.16, Temp:34.1°C, Brown, opaque with gravel in sample jug	0-2m = bentonite/grout seal	
10			Clay: Light brown chips with red clayey matrix composing ~80% of sample, poorly sorted chips 0.5-4cm diameter, subrounded to angular.			EC:950uS/cm, pH:8.11, Temp:34.7°C, Chocolate brown, opaque	100mm CL18 PVC Blank Casing	
20	Upper Calcrete		Calcrete: White to cream calcrete, highly weathered and vuggy, 10% crystalline hard silcrete. 26-28m pink staining of calcrete.			EC:1587uS/cm, pH:7.94, Temp:32.5°C, Orange-brown, 20% transparent, fines settling		
30			Calcrete: As above, but with pink-brown colour, increase clay content.			EC:2037uS/cm, pH:8.11, Temp:29.9°C, Red-brown, opaque	2-94.5m = gravel pack (3.2-6.4mm)	
40			Pisolite: Red-brown, small diameter 1-5mm chips, moderately sorted, minor magnetism			EC:2056uS/cm, pH:8.14, Temp:30.5°C, Red-brown, opaque		
50	CID Pisolit		Hardcap: Blue-brown chips with staining, primarily goethitic mineralisation, especially 48-50m, minor shales, poorly sorted.			EC:2940uS/cm, pH:8.07, Temp:30.2°C, Orange-brown, opaque		
60	Marra Mamba		Hardcap: Yellow-brown, increase limonitic goethite/shale, subrounded-subangular.			EC:2980uS/cm, pH:8.04, Temp:30.4°C, Orange-brown, opaque		
70			BIF: Blue, white, hard angular BIF chips, red-purple ferruginsed shales, minor brown streak goethite, minor grey cloudy to clear chert very hard.			EC:3000uS/cm, pH:8.09, Temp:30.6°C, Red-brown, opaque	10.5-94.5m = 100mm CL18 PVC Slotted Casing, 1mm aperture	
80			BIF: Dark brown and blue banded BIF with yellow goethitic shale, layered chert bands, angular, 70-72m very ground up samples, 72-74m quartz crystals and green tinted cherts.			EC:2970uS/cm, pH:8.05, Temp:31.2°C, Orange-brown, opaque		
90			Dolomite: Dark blue crystalline dolomite, moderately sorted and fine grain texture, minor chert and black-grey soft shales.			EC:3070uS/cm, pH:7.97, Temp:30.4°C, Orange-brown, opaque		
			Dolomite: As above, but darker blue and increase soft shale.			EC:2900uS/cm, pH:8.13, Temp:30.3°C, Light brown, semi-transparent. Water level over v-notch.		
			Dolomite: Grey-green-blue dolomite, very hard, with minor metallic lustre silver-gold pyrite 90-94m.			EC:3200uS/cm, pH:8.1, Temp:30.1°C, Cloudy white, 90% transparent		
						EC:3050uS/cm, pH:8.1, Temp:31.2°C, Cloudy white, 90% transparent		
						EC:2970uS/cm, pH:8.07, Temp:31.9°C, Slightly grey, 90% transparent		



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COMPOSITE WELL LOG

Bore No: MDPZ9221

Client: Roy Hill

Project: Mulga Downs PFS Investigation

Commenced: 7/12/2021
Completed: 12/12/2021
Drilled: Pentium Hydro
Logged By: CS

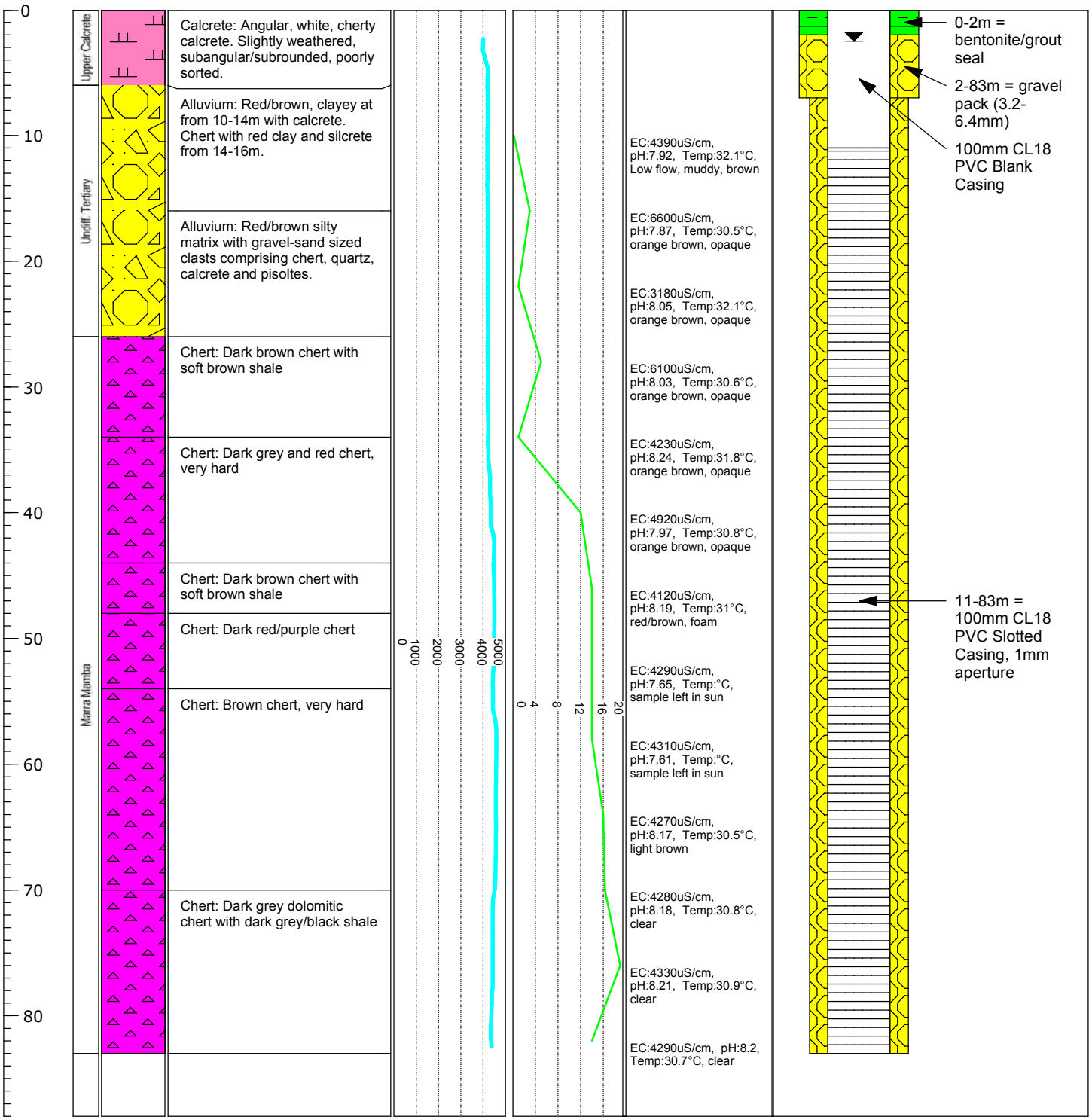
Method: DR / DTH
Fluid: Air
Bit Record: 0-7m = 230mm
70-83m = 190mm

Area: Mulga West
GL Elevation: 389.85 mAHD
Easting: 609649
Northing: 7560972
Projection: MGA94 Zone 50

Static Water Level: 2.50 mbtoc
Date: 13/12/2021

Remarks: Stick up = 0.49m

Depth (mbgl)	Hydro Strat	Graphic Log	Lithological Description	EC (µS/cm)	Drilling Yield (L/s)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0 – 5	Upper Calcrete		Calcrete: Angular, white, cherty calcrete. Slightly weathered, subangular/subrounded, poorly sorted.			EC:4390uS/cm, pH:7.92, Temp:32.1°C, Low flow, muddy, brown	0-2m = bentonite/grout seal	
5 – 14	Undiff. Tertiary		Alluvium: Red/brown, clayey at from 10-14m with calcrete. Chert with red clay and silcrete from 14-16m.			EC:6600uS/cm, pH:7.87, Temp:30.5°C, orange brown, opaque	2-83m = gravel pack (3.2-6.4mm)	
14 – 25	Undiff. Tertiary		Alluvium: Red/brown silty matrix with gravel-sand sized clasts comprising chert, quartz, calcrete and pisoltes.			EC:3180uS/cm, pH:8.05, Temp:32.1°C, orange brown, opaque	100mm CL18 PVC Blank Casing	
25 – 30	Marra Mamba		Chert: Dark brown chert with soft brown shale			EC:6100uS/cm, pH:8.03, Temp:30.6°C, orange brown, opaque		
30 – 40	Marra Mamba		Chert: Dark grey and red chert, very hard			EC:4230uS/cm, pH:8.24, Temp:31.8°C, orange brown, opaque		
40 – 45	Marra Mamba		Chert: Dark brown chert with soft brown shale			EC:4920uS/cm, pH:7.97, Temp:30.8°C, orange brown, opaque		
45 – 50	Marra Mamba		Chert: Dark red/purple chert			EC:4120uS/cm, pH:8.19, Temp:31°C, red/brown, foam	11-83m = 100mm CL18 PVC Slotted Casing, 1mm aperture	
50 – 70	Marra Mamba		Chert: Brown chert, very hard			EC:4290uS/cm, pH:7.65, Temp:°C, sample left in sun		
70 – 83	Marra Mamba		Chert: Dark grey dolomitic chert with dark grey/black shale			EC:4310uS/cm, pH:7.61, Temp:°C, sample left in sun		
						EC:4270uS/cm, pH:8.17, Temp:30.5°C, light brown		
						EC:4280uS/cm, pH:8.18, Temp:30.8°C, clear		
						EC:4330uS/cm, pH:8.21, Temp:30.9°C, clear		
						EC:4290uS/cm, pH:8.2, Temp:30.7°C, clear		



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COMPOSITE WELL LOG

Bore No: MDPZ9222S

Client: Roy Hill / Han Roy
Project: Mulga Downs EPFS

Commenced:	05/08/2023	**Method:**	DR / DTH	**Area:**	Malay Well
Completed:	17/08/2023	**Fluid:**	Air	**GL Elevation:**	tbc
Drilled:	Pentium Hydro	**Bit Record:**	0-106m= 241mm	**Easting:**	6439999
Logged By:	SP/AE		106-117m= 191mm	**Northing:**	7550197
				Projection:	GDA94 Zone 50
Static Water Level:	5.41 mbtoc	**Date:**	28/08/2023	**Remarks:**	Stick-Up = 0.6m

Depth (mbgl)	Strat / Hydro	Graphic Log	Lithological Description	EC Profile (µS/cm)	Drilling Yield (L/s)	Field Notes	Well Completion Diagram	Well Completion Notes
0–120	Upper Calcrete / Undiff Tert / CID / Basal Crete / WA? / West Angela		Clay: Red-brown, sub angular to rounded, sand size pisolites in a clay matrix. Minor BIF, calcrete and quartzite. Calcrete: Pale brown - cream. Increasing shale chips with depth. Reacts strongly with HCL. Clayey Gravel: Brown, sub angular to rounded, sand to pebble size BIF, with some pisolites, purple shale and calcrete in a clay matrix. Evidence mineralisation with geothite. Pistolite: Dark brown, sub rounded to rounded, sand to gravel size. Calcrete: White-biege. Reacts strongly with HCL. Reported by Driller as "hard drilling". Clay: Red-white with clasts of calcrete. Shale: Dark brown, sub angular to sub rounded shale with BIF and clasts white clay. Evidence of mineralisation with geothite. Clay: Pink-white with pisolites and clasts dark grey shale increasing with depth. Shale: Pink-white with pisolites and clasts dark grey shale increasing with depth. Clay: White and pink. Shale: Dark grey with evidence of pyrite and some mineralisation with geothite and hematite. Leaves appearance of oily sheen on water at cyclone. BIF: Grey-brown with fragments of chert and shale. Evidence of mineralisation with geothite and magnetite - magnetic from 102m bgl. Evidence of pyrite. Becoming fresher with depth between 116-117m bgl. Potential asbestos fibres encountered between 112-116m.	0 6,000 12,000 18,000 24,000 30,000	0 20 40 60 80 100	pH = 8.08, EC= 1909, Airlift measurement method: Bucket pH = 8.30, EC= 3990, Airlift measurement method: Bucket pH = 8.38, EC= 4530, Airlift measurement method: Bucket pH = 8.35, EC= 4550, Airlift measurement method: Bucket pH = 8.36, EC= 4690, Airlift measurement method: Bucket pH = 8.36, EC= 4690, Airlift measurement method: Bucket pH = 8.37, EC= 4710, Airlift measurement method: Bucket Driller reported "patchy ground transitioning between hard and broken ground" 46-106m pH = 8.47, EC= 4770, Airlift measurement method: Bucket pH = 8.52, EC= 4660, Airlift measurement method: Bucket pH = 8.28, EC= 5020, Airlift measurement method: V-Notch pH = 8.45, EC= 5510, Airlift measurement method: V-Notch pH = 8.34, EC= 5510, Airlift measurement method: V-Notch pH = 8.30, EC= 6670, Airlift measurement method: V-Notch pH = 8.17, EC= 13690, Airlift measurement method: V-Notch pH = 8.03, EC= 18690, Airlift measurement method: V-Notch pH = 7.94, EC= 17770, pH = 8.03, Airlift measurement method: V-Notch pH = 8.08,, EC= 18300, Airlift measurement method: V-Notch pH = 7.93, , EC= 18360, Airlift measurement method: V-Notch Hole terminated at 117m bgl due to potential asbestos fibres encountered 112-116m bgl.	Bentonite/Grout Seal (0-2m) 100 mm CL18 Blank Casing (0-10m) Graded Gravel Pack 3.2-6.4mm (2-40m) 100mm CL18 Slotted Casing 1mm Aperture (10-40m) Bentonite seal Collapsed hole	

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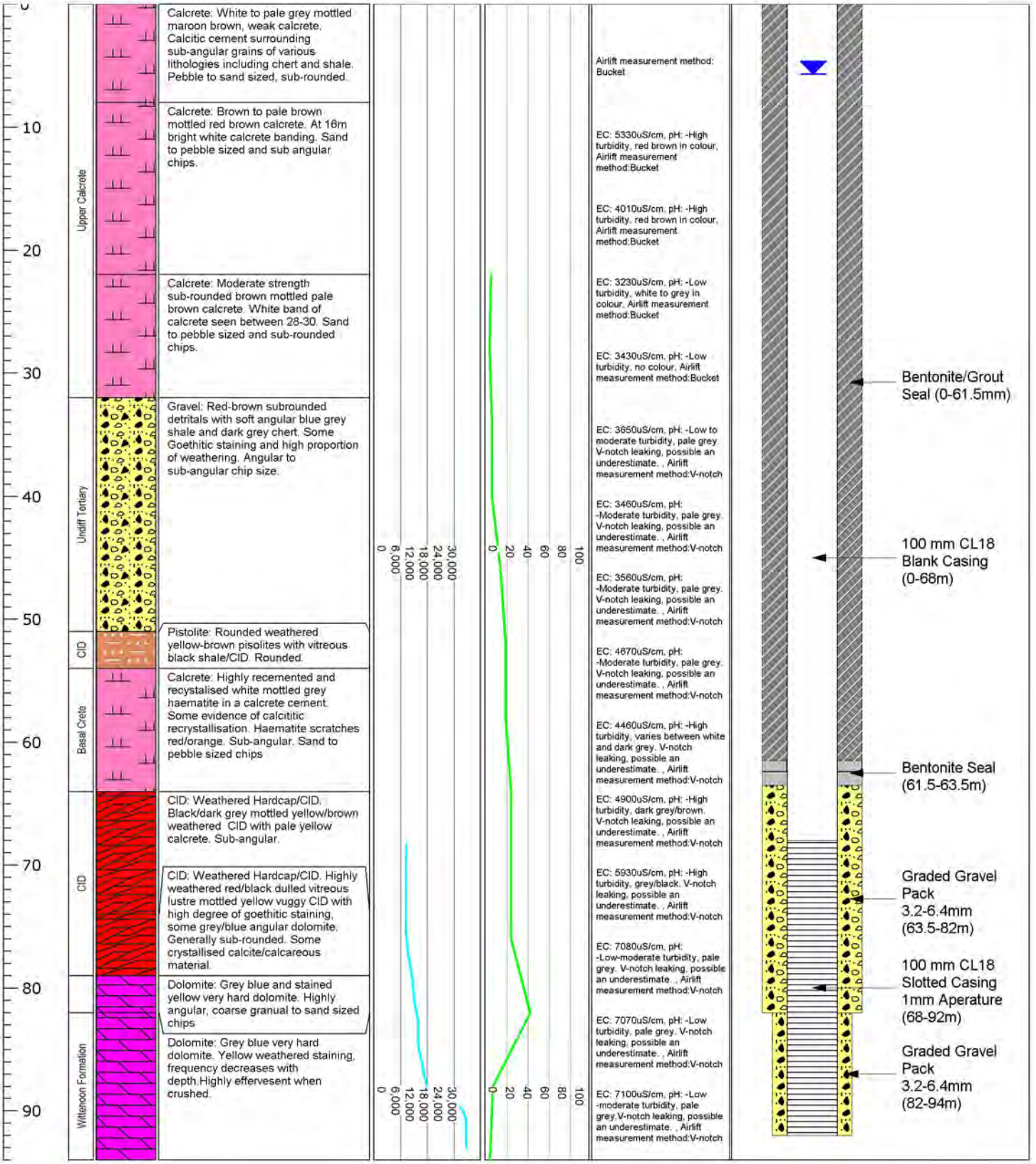
COMPOSITE WELL LOG

Bore No: MDPZ9223D

Client: Roy Hill / Han Roy
Project: Mulga Downs EPFS

Commenced:	21/09/2023	**Method:**	DR / DTH	**Area:**	Pilbara
Completed:	29/09/2023	**Fluid:**	air	**GL Elevation:**	tbc
Drilled:	Pentium Hydro	**Bit Record:**	82-94m=191 mm	**Easting:**	648835
Logged By:	SP/AE		0-82m = 241mm	**Northing:**	7546202
				Projection:	GDA94 Zone 50
Static Water Level:	5.65 mbtc	**Date:**	29/09/2023	**Remarks:**	Stick-up = 0.53m

Depth (mbgl)	Strat / Hydro	Graphic Log	Lithological Description	EC Profile (µS/cm)	Drilling Yield (L/s)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0–10	Upper Calcrete		Calcrete: White to pale grey mottled maroon brown, weak calcrete. Calcitic cement surrounding sub-angular grains of various lithologies including chert and shale. Pebble to sand sized, sub-rounded.			Airlift measurement method: Bucket		
10–20	Upper Calcrete		Calcrete: Brown to pale brown mottled red brown calcrete. At 16m bright white calcrete banding. Sand to pebble sized and sub angular chips.			EC: 5330uS/cm, pH: -High turbidity, red brown in colour, Airlift measurement method:Bucket EC: 4010uS/cm, pH: -High turbidity, red brown in colour, Airlift measurement method:Bucket		
20–30	Upper Calcrete		Calcrete: Moderate strength sub-rounded brown mottled pale brown calcrete. White band of calcrete seen between 28-30. Sand to pebble sized and sub-rounded chips.			EC: 3230uS/cm, pH: -Low turbidity, white to grey in colour, Airlift measurement method:Bucket EC: 3430uS/cm, pH: -Low turbidity, no colour, Airlift measurement method:Bucket		
30–50	Undiff Tertiary		Gravel: Red-brown subrounded detritals with soft angular blue grey shale and dark grey chert. Some Goethitic staining and high proportion of weathering. Angular to sub-angular chip size.			EC: 3650uS/cm, pH: -Low to moderate turbidity, pale grey. V-notch leaking, possible an underestimate. , Airlift measurement method:V-notch EC: 3460uS/cm, pH: -Moderate turbidity, pale grey. V-notch leaking, possible an underestimate. , Airlift measurement method:V-notch EC: 3560uS/cm, pH: -Moderate turbidity, pale grey. V-notch leaking, possible an underestimate. , Airlift measurement method:V-notch		
50–52	CID		Pistolite: Rounded weathered yellow-brown pisolites with vitreous black shale/CID. Rounded.			EC: 4670uS/cm, pH: -Moderate turbidity, pale grey. V-notch leaking, possible an underestimate. , Airlift measurement method:V-notch		
52–60	Basal Crete		Calcrete: Highly recemented and recystalised white mottled grey haematite in a calcrete cement. Some evidence of calcititic recrystallisation. Haematite scratches red/orange. Sub-angular. Sand to pebble sized chips			EC: 4460uS/cm, pH: -High turbidity, varies between white and dark grey. V-notch leaking, possible an underestimate. , Airlift measurement method:V-notch		
60–70	CID		CID: Weathered Hardcap/CID. Black/dark grey mottled yellow/brown weathered CID with pale yellow calcrete. Sub-angular.			EC: 4900uS/cm, pH: -High turbidity, dark grey/brown. V-notch leaking, possible an underestimate. , Airlift measurement method:V-notch		
70–80	CID		CID: Weathered Hardcap/CID. Highly weathered red/black dulled vitreous lustre mottled yellow vuggy CID with high degree of goethitic staining, some grey/blue angular dolomite. Generally sub-rounded. Some crystallised calcite/calcareous material.			EC: 5930uS/cm, pH: -High turbidity, grey/black. V-notch leaking, possible an underestimate. , Airlift measurement method:V-notch EC: 7080uS/cm, pH: -Low-moderate turbidity, pale grey. V-notch leaking, possible an underestimate. , Airlift measurement method:V-notch		
80–82	Wittenoon Formation		Dolomite: Grey blue and stained yellow very hard dolomite. Highly angular, coarse granual to sand sized chips			EC: 7070uS/cm, pH: -Low turbidity, pale grey. V-notch leaking, possible an underestimate. , Airlift measurement method:V-notch		
82–90	Wittenoon Formation		Dolomite: Grey blue very hard dolomite. Yellow weathered staining, frequency decreases with depth.Highly effervesent when crushed.			EC: 7100uS/cm, pH: -Low -moderate turbidity, pale grey.V-notch leaking, possible an underestimate. , Airlift measurement method:V-notch	Bentonite/Grout Seal (0-61.5mm) 100 mm CL18 Blank Casing (0-68m) Bentonite Seal (61.5-63.5m) Graded Gravel Pack 3.2-6.4mm (63.5-82m) 100 mm CL18 Slotted Casing 1mm Aperature (68-92m) Graded Gravel Pack 3.2-6.4mm (82-94m)	



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COMPOSITE WELL LOG

Bore No: MDPZ9223S

Client: Roy Hill / Han Roy
Project: Mulga Downs EPFS

Commenced:	10/11/2023	**Method:**	DR / DTH	**Area:**	Malay Well
Completed:	14/10/23	**Fluid:**	Air	**GL Elevation:**	tbc
Drilled:	Pentium Hdyro	**Bit Record:**	0-29m = 241mm	**Easting:**	648838
Logged By:	SP/AE		29-30m = 191mm	**Northing:**	7546180
				Projection:	GDA94 Zone 50
Static Water Level:	5.65mbtoc	**Date:**	16/10/2023	**Remarks:**	Stick-up = 0.57m

Depth (mbgl)	Strat / Hydro	Graphic Log	Lithological Description	EC Profile (µS/cm)	Drilling Yield (L/s)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0 – 10	Upper Calcrete		Calcrete: Pale grey and brown. Red shale and chert in a cemented matrix. Weathered.			No flow	Bentonite Seal (0-2m) 100 mm CL18 Blank Casing (0-8m)	
10 – 20	Upper Calcrete		Calcrete: Light brown and grey. Red shale and pisolites in a cemented matrix. Weathered.			EC: 4250 uS/cm, pH: 8.3 ,Water turbid, Airlift measurement method:Bucket EC: 3840 uS/cm, pH: 8.34 ,Water turbid, Airlift measurement method:Bucket	Graded Gravel Pack 3.2-6.4mm (2-30m) 100 mm CL18 Slotted Casing 1mm Apperture (9-30m)	
20 – 30	Upper Calcrete					EC: 3530 uS/cm, pH: 8.33 ,Water turbid, Airlift measurement method:Bucket EC: 3370 uS/cm, pH: 8.31 ,Water less turbid, Airlift measurement method:Bucket EC: 3390 uS/cm, pH: 8.3 ,Water clearing up. Drilled open hole from 28m bgl., Airlift measurement method:Bucket		
30 – 40	Upper Calcrete							
40 – 50	Upper Calcrete							

EC Profile (µS/cm): 0, 6,000, 12,000, 18,000, 24,000, 30,000
Drilling Yield (L/s): 0, 12, 24, 36, 48, 60

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COMPOSITE WELL LOG

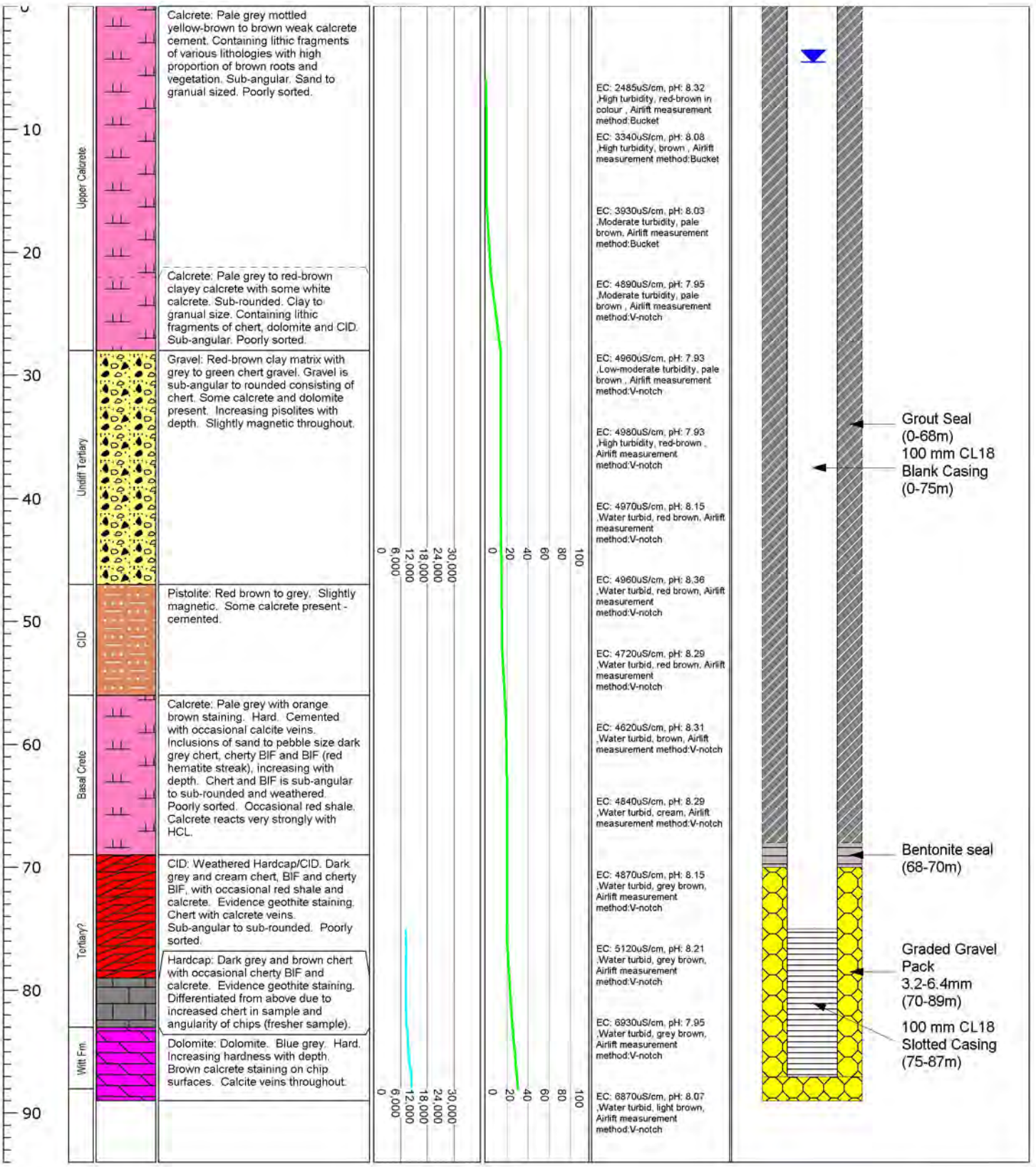
Bore No: MDPZ9224D

Client: Roy Hill / Han Roy

Project: Mulga Downs EPFS

Commenced:	21/10/2023	**Method:**	DR	**Area:**	Malay Well
Completed:	31/10//2023	**Fluid:**	Air	**GL Elevation:**	tbc
Drilled:	Pentium Hydro	**Bit Record:**	0-89m = 241mm	**Easting:**	647965
Logged By:	SP/AE			**Northing:**	7547379
				Projection:	GDA94 Zone 50
Static Water Level:	4.51mbtoc	**Date:**	31/10/2023	**Remarks:**	Stick-up = 0.365m

Depth (mbgl)	Strat / Hydro	Graphic Log	Lithological Description	EC Profile (µS/cm)	Drilling Yield (L/s)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0–10	Upper Calcrete		Calcrete: Pale grey mottled yellow-brown to brown weak calcrete cement. Containing lithic fragments of various lithologies with high proportion of brown roots and vegetation. Sub-angular. Sand to granual sized. Poorly sorted.			EC: 2485uS/cm, pH: 8.32 ,High turbidity, red-brown in colour , Airlift measurement method:Bucket EC: 3340uS/cm, pH: 8.08 ,High turbidity, brown , Airlift measurement method:Bucket		
10–20	Upper Calcrete		Calcrete: Pale grey to red-brown clayey calcrete with some white calcrete. Sub-rounded. Clay to granual size. Containing lithic fragments of chert, dolomite and CID. Sub-angular. Poorly sorted.			EC: 3930uS/cm, pH: 8.03 ,Moderate turbidity, pale brown, Airlift measurement method:Bucket EC: 4890uS/cm, pH: 7.95 ,Moderate turbidity, pale brown , Airlift measurement method:V-notch		
20–30	Undiff Tertiary		Gravel: Red-brown clay matrix with grey to green chert gravel. Gravel is sub-angular to rounded consisting of chert. Some calcrete and dolomite present. Increasing pisolites with depth. Slightly magnetic throughout.			EC: 4960uS/cm, pH: 7.93 ,Low-moderate turbidity, pale brown , Airlift measurement method:V-notch EC: 4980uS/cm, pH: 7.93 ,High turbidity, red-brown , Airlift measurement method:V-notch		
30–40	Undiff Tertiary					EC: 4970uS/cm, pH: 8.15 ,Water turbid, red brown, Airlift measurement method:V-notch		
40–50	CID		Pistolite: Red brown to grey. Slightly magnetic. Some calcrete present - cemented.			EC: 4960uS/cm, pH: 8.36 ,Water turbid, red brown, Airlift measurement method:V-notch EC: 4720uS/cm, pH: 8.29 ,Water turbid, red brown, Airlift measurement method:V-notch		
50–60	Basal Cretc		Calcrete: Pale grey with orange brown staining. Hard. Cemented with occasional calcite veins. Inclusions of sand to pebble size dark grey chert, cherty BIF and BIF (red hematite streak), increasing with depth. Chert and BIF is sub-angular to sub-rounded and weathered. Poorly sorted. Occasional red shale. Calcrete reacts very strongly with HCL.			EC: 4620uS/cm, pH: 8.31 ,Water turbid, brown, Airlift measurement method:V-notch		
60–70	Basal Cretc					EC: 4840uS/cm, pH: 8.29 ,Water turbid, cream, Airlift measurement method:V-notch		
70–80	Tertiary?		CID: Weathered Hardcap/CID. Dark grey and cream chert, BIF and cherty BIF, with occasional red shale and calcrete. Evidence geothite staining. Chert with calcrete veins. Sub-angular to sub-rounded. Poorly sorted.			EC: 4870uS/cm, pH: 8.15 ,Water turbid, grey brown, Airlift measurement method:V-notch EC: 5120uS/cm, pH: 8.21 ,Water turbid, grey brown, Airlift measurement method:V-notch		
80–90	Tertiary? / Witt Fm		Hardcap: Dark grey and brown chert with occasional cherty BIF and calcrete. Evidence geothite staining. Differentiated from above due to increased chert in sample and angularity of chips (fresher sample). Dolomite: Dolomite. Blue grey. Hard. Increasing hardness with depth. Brown calcrete staining on chip surfaces. Calcite veins throughout.			EC: 6930uS/cm, pH: 7.95 ,Water turbid, grey brown, Airlift measurement method:V-notch EC: 6870uS/cm, pH: 8.07 ,Water turbid, light brown, Airlift measurement method:V-notch		



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COMPOSITE WELL LOG

Bore No: MDPZ9224S

Client: Roy Hill / Han Roy
Project: Mulga Downs EPFS

Commenced:	15/10/2023	**Method:**	DR / DTH	**Area:**	Malay Well
Completed:	20/10/2023	**Fluid:**	Air	**GL Elevation:**	tbc
Drilled:	Pentium Hydro	**Bit Record:**	0-52m = 241mm	**Easting:**	647970
Logged By:	SP/AE		52-52.5m = 191mm	**Northing:**	7547389
				Projection:	GDA94 Zone 50
Static Water Level:	4.53mbtoc	**Date:**	20/10/2023	**Remarks:**	Stick-up = 0.4m

Depth (mbgl)	Strat / Hydro	Graphic Log	Lithological Description	EC Profile (µS/cm)	Drilling Yield (L/s)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0 – 90	Upper Calcrete / Undiff Tertiary / CID		Calcrete: Weak white mottled red-brown clayey calcrete. Sub-angular to rounded. Poorly sorted	0 – 6,000 – 12,000 – 18,000 – 24,000 – 30,000	0 – 20 – 40 – 60 – 80 – 100	EC: 5030uS/cm, pH: 8.21 ,Water cloudy brown, Airlift measurement method:Bucket	Grout Seal (0-20m)	
			Calcrete: Pale grey mottled yellow-brown to brown weak calcrete cement. Containing lithic fragments of various lithologies . Sub-angular. Sand to granual sized. Poorly sorted.			EC: 4680uS/cm, pH: 7.8 ,Brown, moderate turbidity. Airlift measurement method:Bucket	100 mm CL18 Blank Casing (0-28m)	
			Calcrete: Red-brown clayey calcrete with some white calcrete. Sub-rounded. Clay to granual size. Containing lithic fragments of chert, dolomite and CID. Sub-angular. Poorly sorted.			EC: 4850uS/cm, pH: 8.01 ,Pale grey, moderate turbidity. Airlift measurement method:V-notch	Bentonite seal (20-22m)	
			Clayey Gravel: Red-brown clay matrix with grey to green chert gravel. Gravel is sub-rounded to sub-angular consisting of chert. Some calcrete present.			EC: 4860uS/cm, pH: 7.95 ,Pale grey, low turbidity., Airlift measurement method:V-notch		
			Clayey Gravel: Red-brown clay matrix with gravel of chert, CID and BIF. Gravel is sub-rounded to sub-angular consisting of chert. Some calcrete present.			EC: 4760uS/cm, pH: 8.14 ,Pale grey to brown, moderate turbidity., Airlift measurement method:V-notch	Graded Gravel Pack 3.2-6.4mm (22-52.5m)	
			Gravel and Sand: Red-brown mottled dark grey sandy gravel. Gravel of sub-rounded sub-angular calcrete, chert, BIF and CID.			EC: 4890uS/cm, pH: 8.06 ,Red brown, high turbidity., Airlift measurement method:V-notch	100 mm CL18 Slotted Casing (28-52m)	
			Pistolite: Red-brown silty matrix with dark grey magnetitic pisolites. Pisolites are rounded with su-angular fragments of matrix. isolites. Moderately sorted. Individiual pisolites hard, matrix weak.			EC: 4840uS/cm, pH: 7.91 ,Red brown, high turbidity., Airlift measurement method:V-notch		
			Calcrete: Hard white and pale brown calcrete. Angular. Highly effervesent. Granual to pebble sized chips.			EC: 4630uS/cm, pH: 7.87 ,Pale cream, low turbidity. Airlift measurement method:V-notch		

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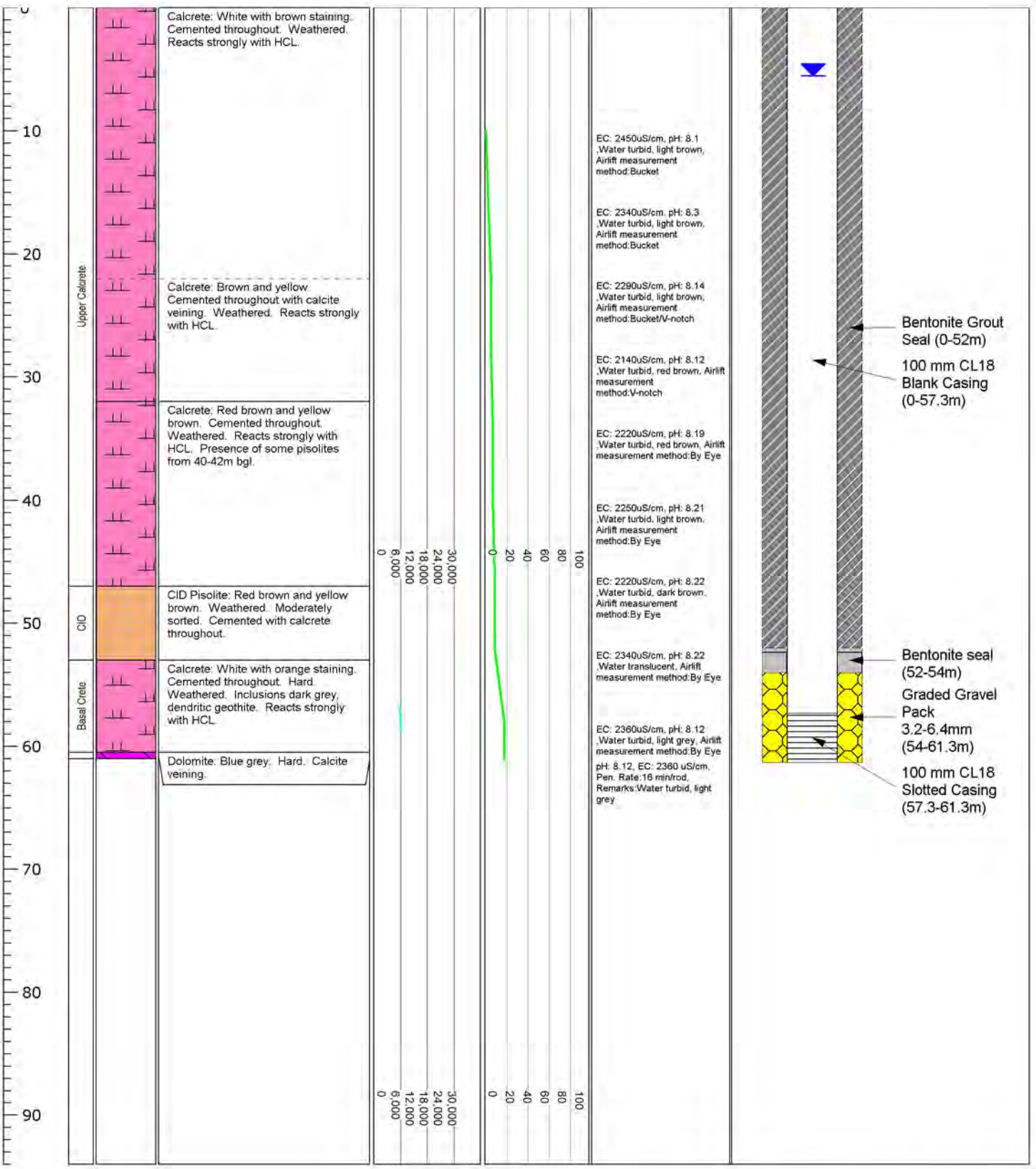
COMPOSITE WELL LOG

Bore No: MDPZ9225

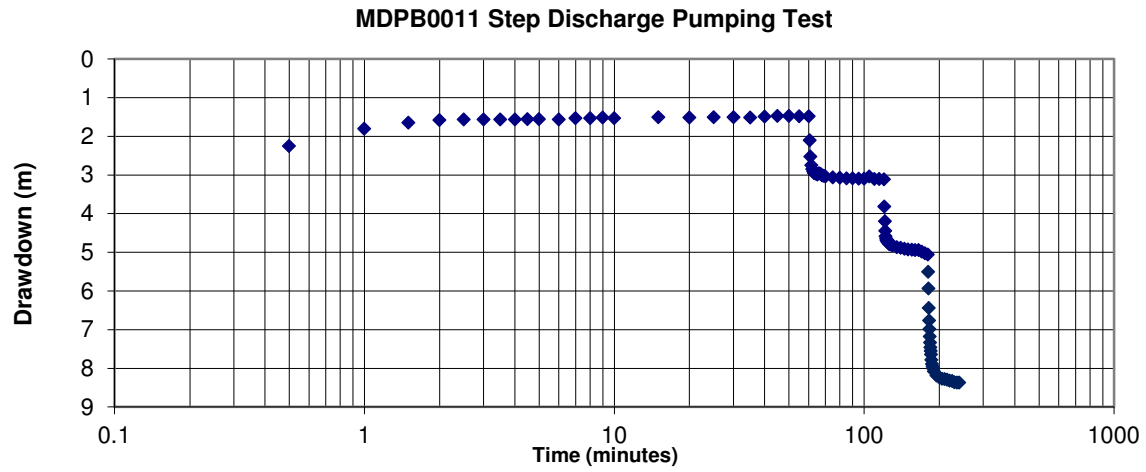
Client: Roy Hill / Han Roy
Project: Mulga Downs EPFS

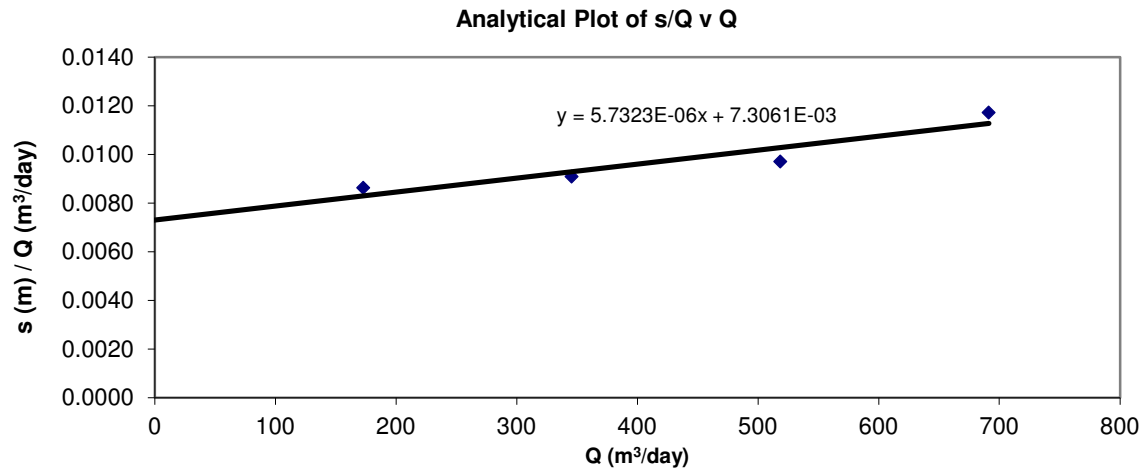
Commenced:	11/01/2023	**Method:**	DR	**Area:**	Malay Well
Completed:	11/05//2023	**Fluid:**	Air	**GL Elevation:**	TBC
Drilled:	Pentium Hydro	**Bit Record:**	0-63.1m= 241 mm	**Easting:**	649571
Logged By:	SP/AE			**Northing:**	7544628
				Projection:	GDA94 Zone 50
Static Water Level:	5.52mbtoc	**Date:**	13/11/2023	**Remarks:**	Stick-up= 0.555m

Depth (mbgl)	Strat / Hydro	Graphic Log	Lithological Description	EC Profile (µS/cm)	Drilling Yield (L/s)	Field Notes	Well Completion: Diagram	Well Completion: Notes
0–10	Upper Calcrete		Calcrete: White with brown staining. Cemented throughout. Weathered. Reacts strongly with HCL.			EC: 2450uS/cm, pH: 8.1 ,Water turbid, light brown, Airlift measurement method:Bucket		
10–20	Upper Calcrete					EC: 2340uS/cm, pH: 8.3 ,Water turbid, light brown, Airlift measurement method:Bucket		
20–30	Upper Calcrete		Calcrete: Brown and yellow. Cemented throughout with calcite veining. Weathered. Reacts strongly with HCL.			EC: 2290uS/cm, pH: 8.14 ,Water turbid, light brown, Airlift measurement method:Bucket/V-notch		
30–40	Upper Calcrete		Calcrete: Red brown and yellow brown. Cemented throughout. Weathered. Reacts strongly with HCL. Presence of some pisolites from 40-42m bgl.			EC: 2140uS/cm, pH: 8.12 ,Water turbid, red brown, Airlift measurement method:V-notch		
40–50	Upper Calcrete					EC: 2220uS/cm, pH: 8.19 ,Water turbid, red brown, Airlift measurement method:By Eye		
50–60	CID		CID Pisolite: Red brown and yellow brown. Weathered. Moderately sorted. Cemented with calcrete throughout.			EC: 2250uS/cm, pH: 8.21 ,Water turbid, light brown, Airlift measurement method:By Eye		
60–70	Basal Crete		Calcrete: White with orange staining. Cemented throughout. Hard. Weathered. Inclusions dark grey, dendritic geothite. Reacts strongly with HCL.			EC: 2220uS/cm, pH: 8.22 ,Water turbid, dark brown, Airlift measurement method:By Eye		
70–80	Basal Crete					EC: 2340uS/cm, pH: 8.22 ,Water translucent, Airlift measurement method:By Eye		
80–90	Basal Crete		Dolomite: Blue grey. Hard. Calcite veining.			EC: 2360uS/cm, pH: 8.12 ,Water turbid, light grey, Airlift measurement method:By Eye pH: 8.12, EC: 2360 uS/cm, Pen. Rate:16 min/rod, Remarks:Water turbid, light grey		



APPENDIX E
PUMPING TEST DATA PLOTS (2019–2023)





$s_{w(n)} = BQ_n + CQ^P_n$ (Rorabaugh's equation)

Where, B = Intercept with y axis (coefficient of aquifer loss or laminar flow)
C = Gradient (coefficient of turbulent flow loss or apparent well loss)
s = Drawdown in the borehole
P = Value determined using Rorabaugh's method of superposition

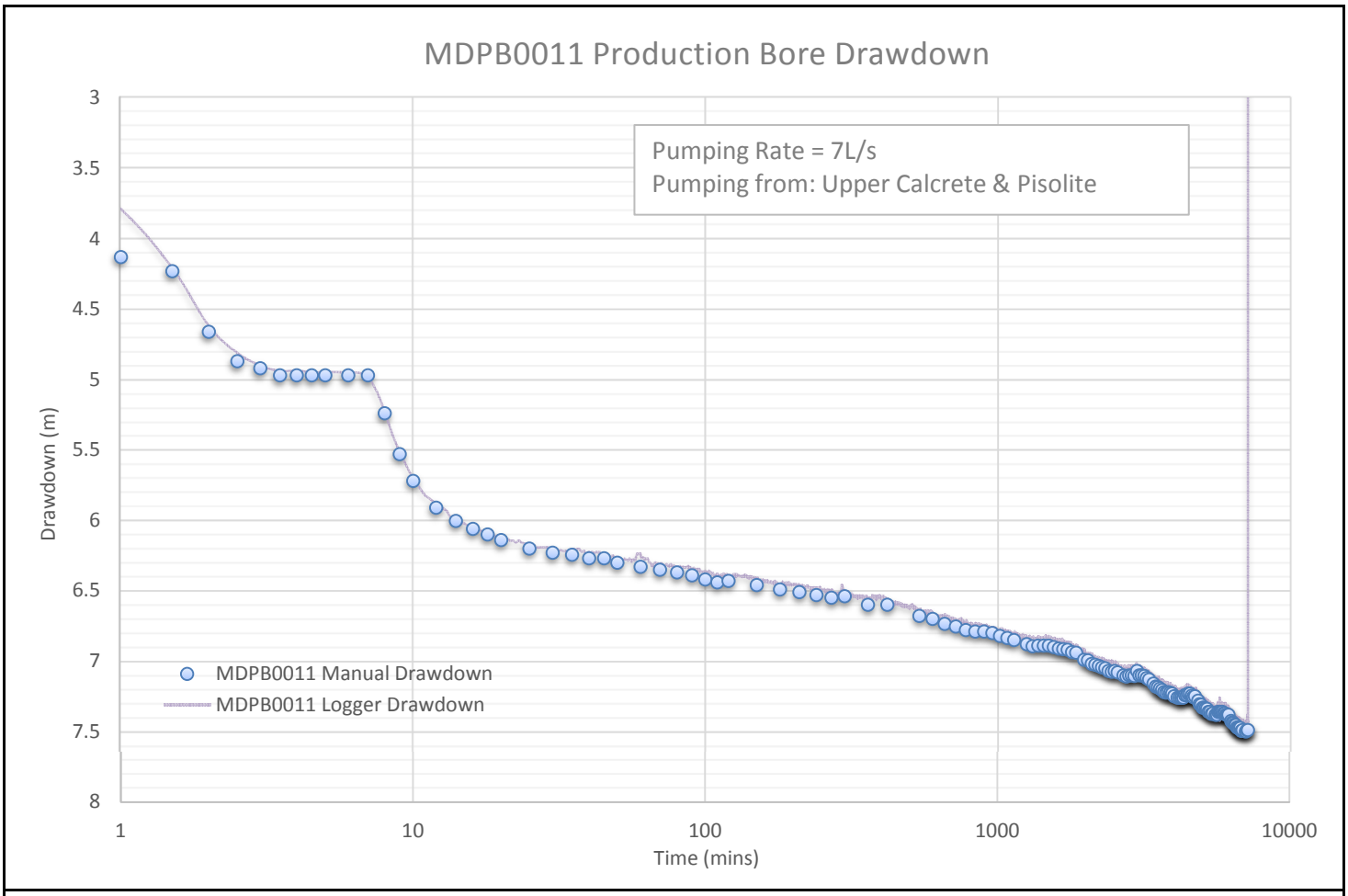
Components of the equation BQ and CQ^2 are termed the aquifer loss and apparent well loss respectively.
They give an indication of the proportion of total drawdown caused by laminar and turbulent flow.

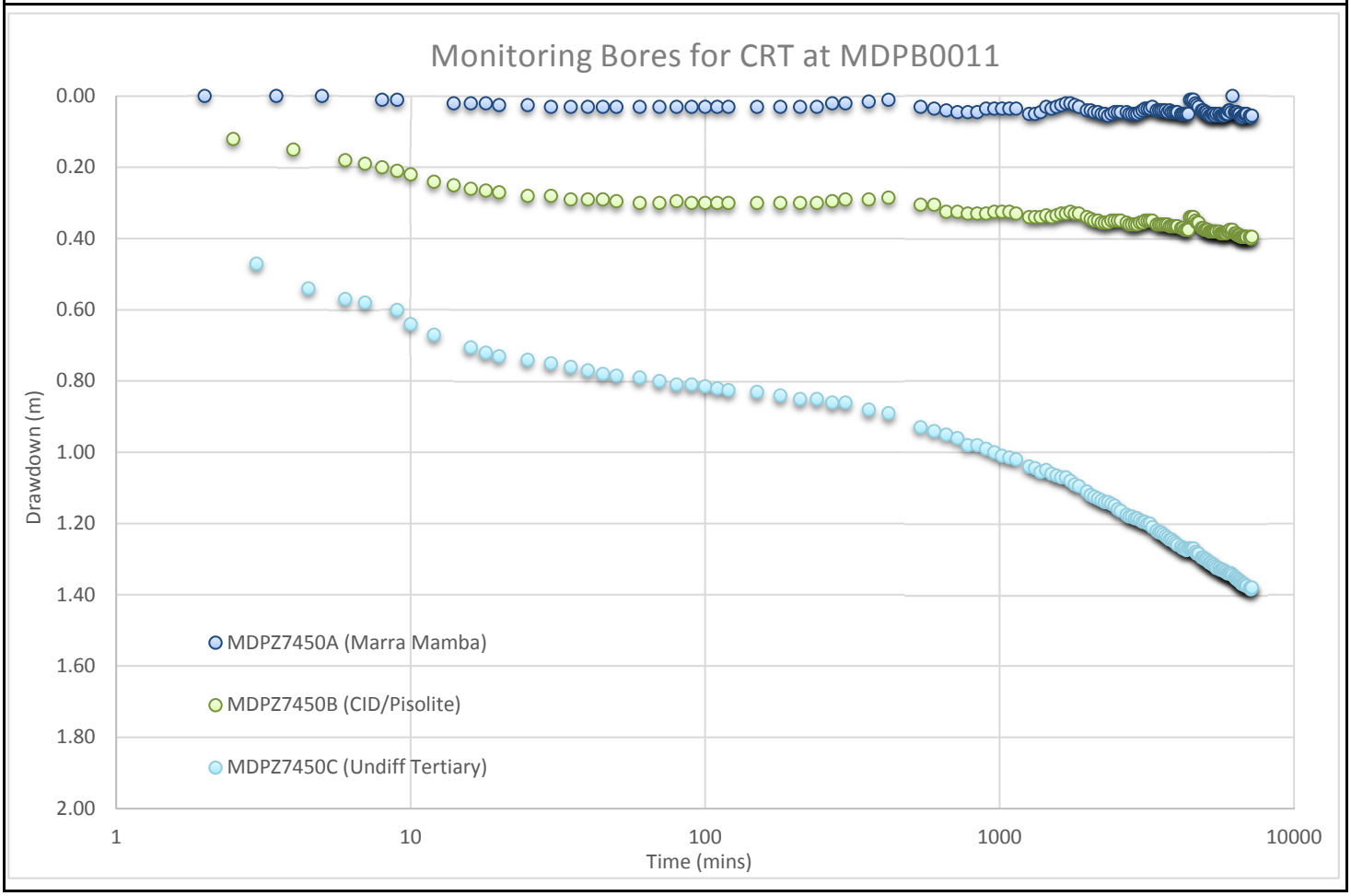
It should be noted:
1. In thin or fissured aquifers large components of well loss are due to high flow velocities in the aquifer rather than inefficient bore design. Therefore, the term "apparent well loss" is better than well loss.
2. In aquifers where the flow horizons are vertically anisotropic, changes in bore performance often relate to changes in the rest water level with respect to the primary aquifer horizons.

$Ew = (BQ/(BQ + CQ^P)) \times 100$

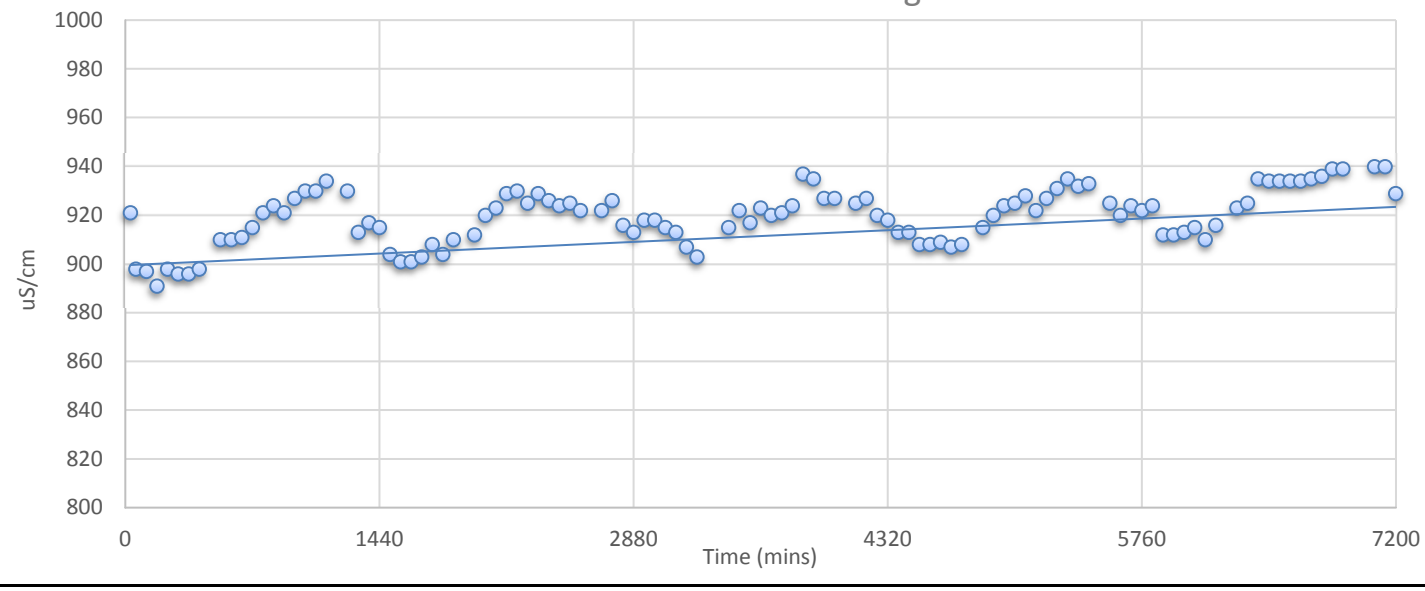
Ew or Well Efficiency represents the proportion of drawdown caused by laminar flow

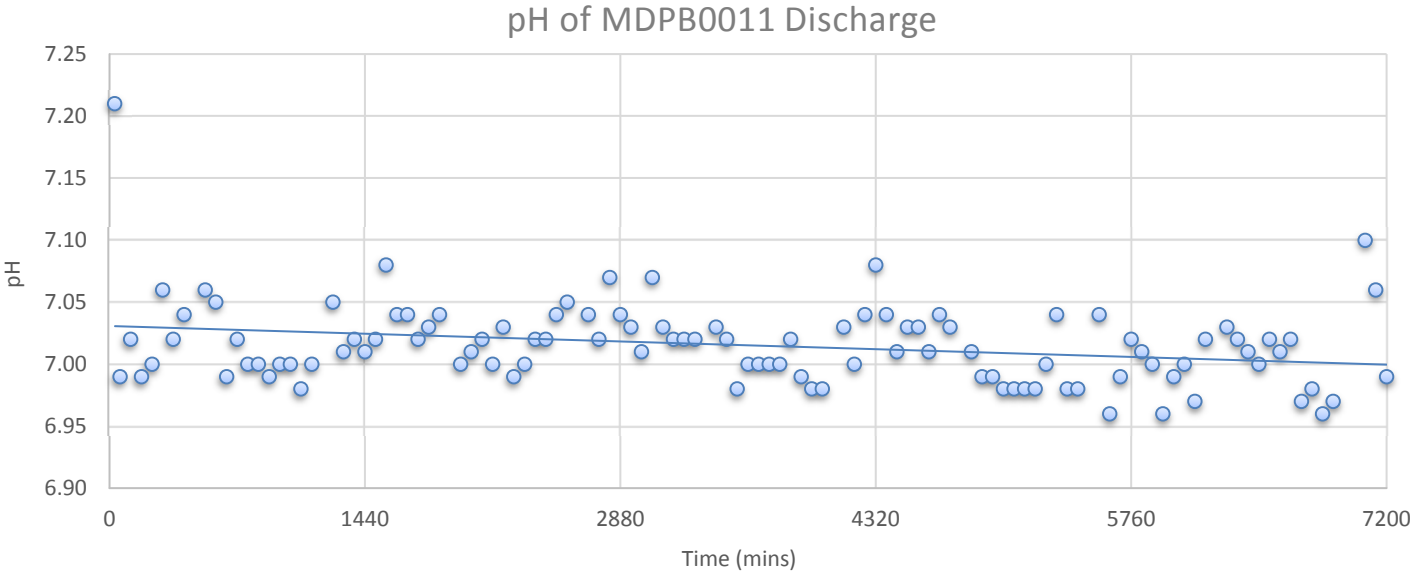
Comparison of Observed and Predicted Drawdowns						
Step (60 min steps)	Discharge (L/s)	Discharge (Q) (m3/d)	Observed Corrected Drawdown (s) (metres)	Predicted Drawdown (metres)	s/Q	Apparent Efficiency (Ew) %
1	2.0	173	1.49	1.43	0.0086	88.06
2	4.0	346	3.14	3.21	0.0091	78.67
3	6.0	518	5.03	5.33	0.0097	71.09
4	8.0	691	8.10	7.79	0.0117	64.84

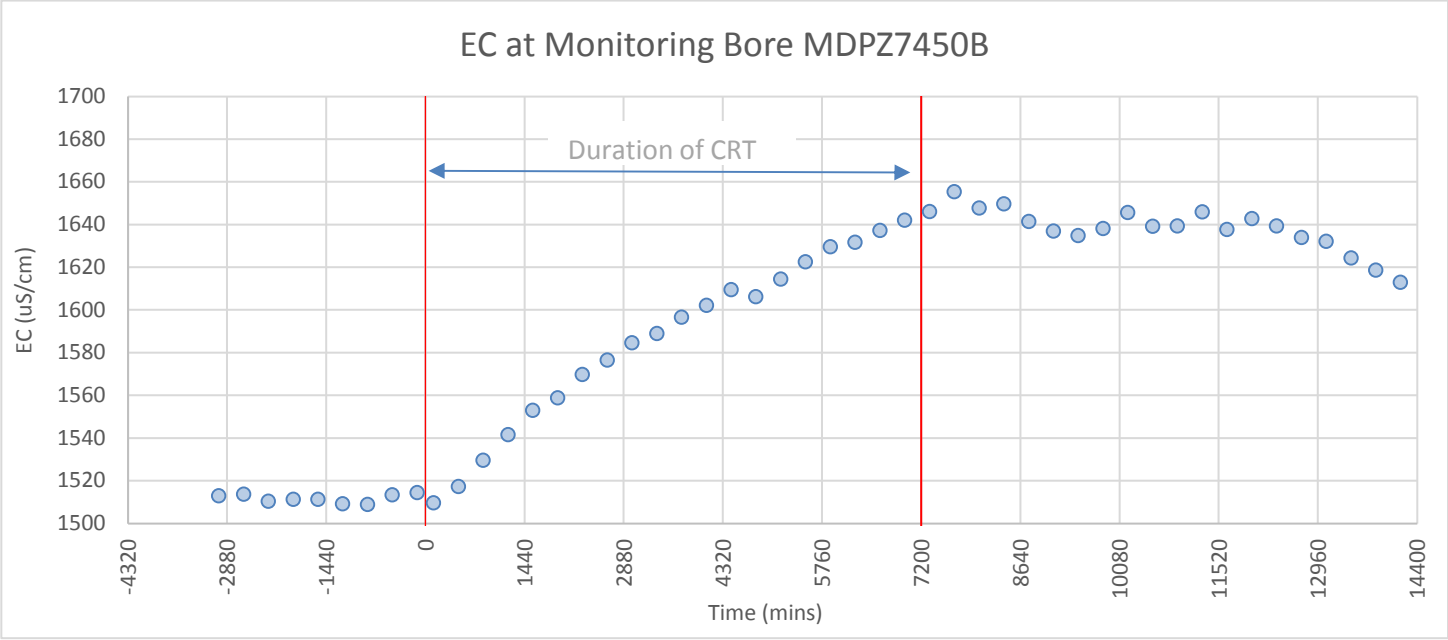


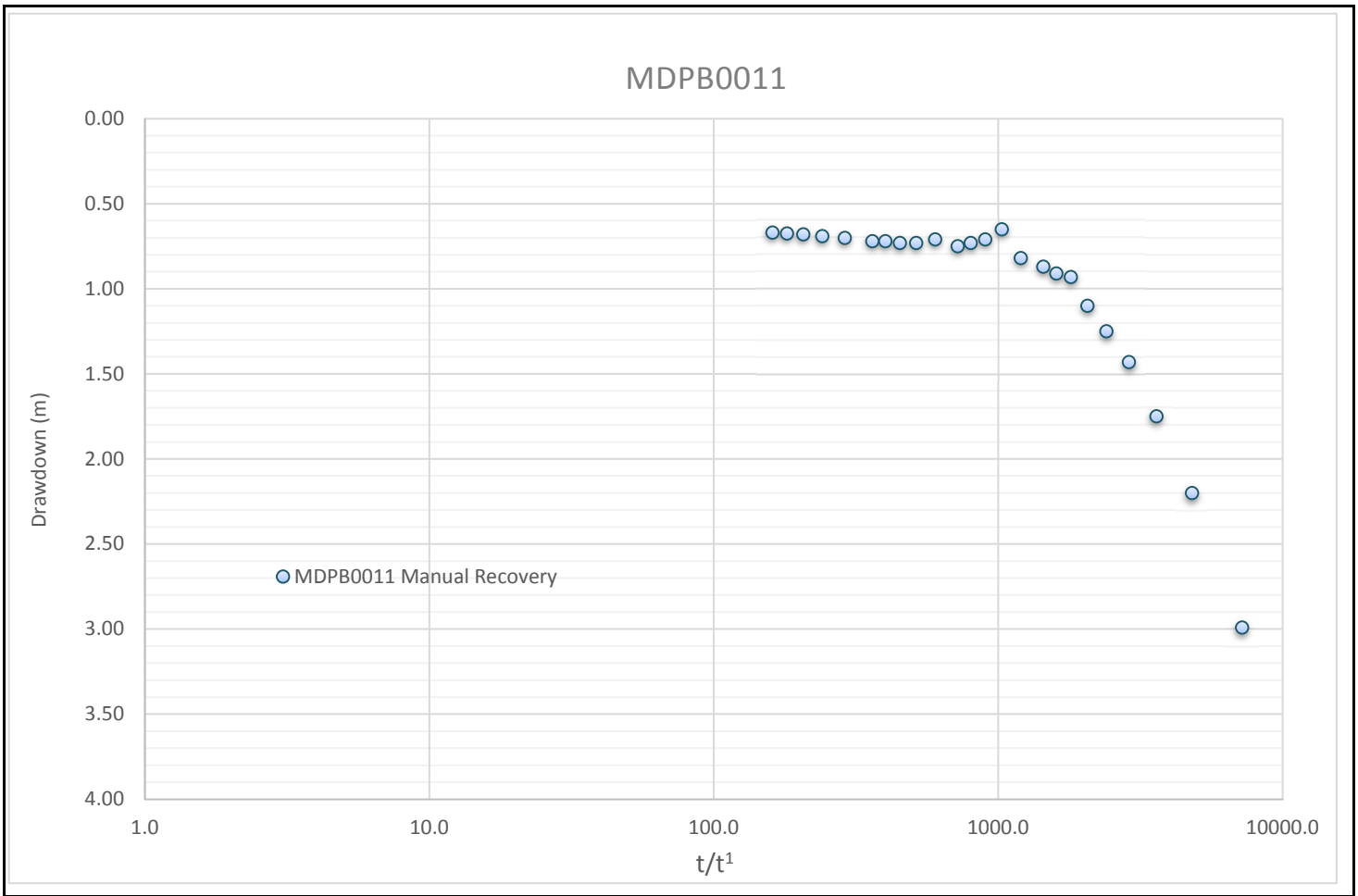


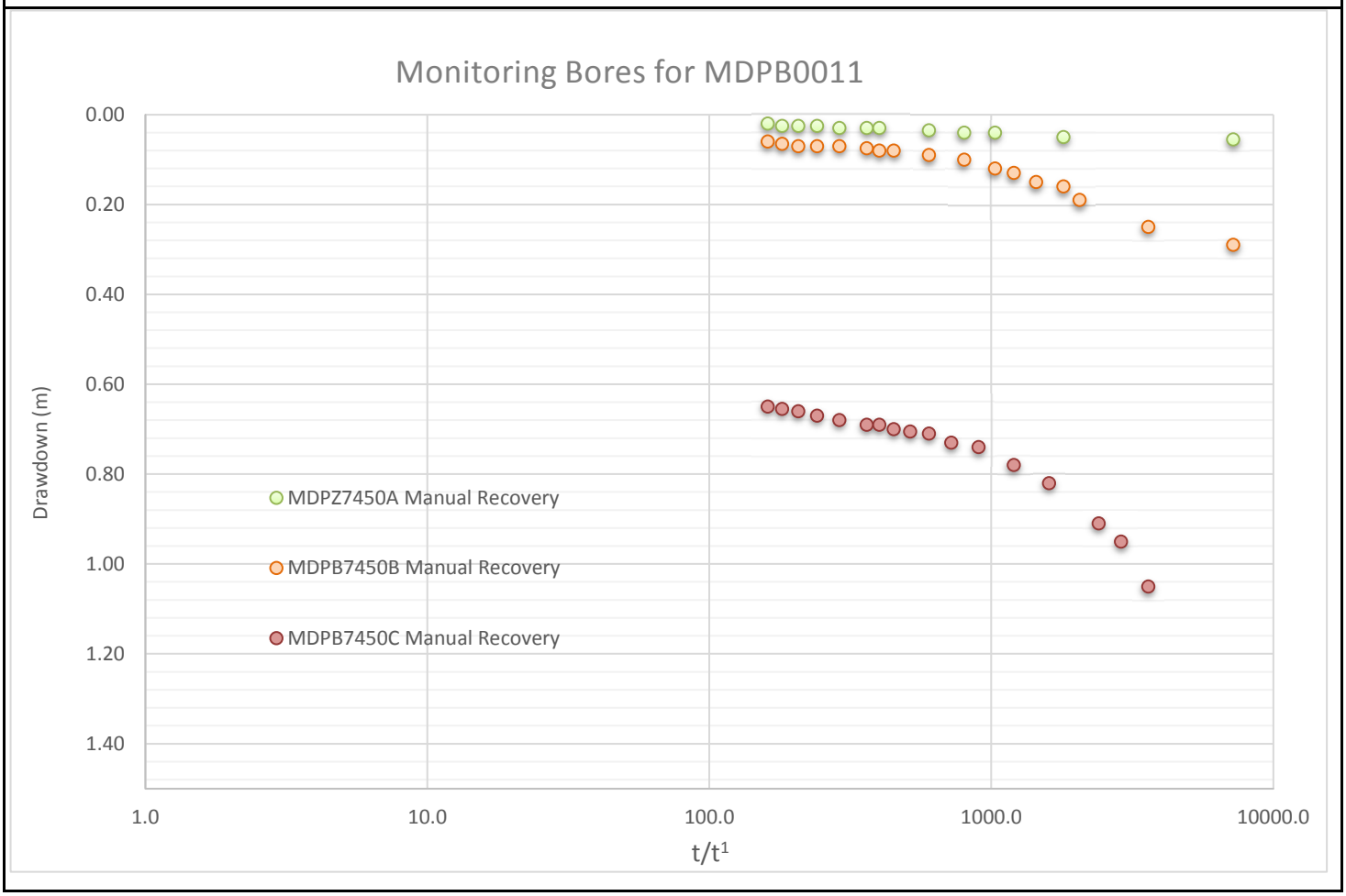
MDPB0011 Constant Rate Test Drawdown


EC of MDPB0011 Discharge
uS/cm
1000
980
960
940
920
900
880
860
840
820
800
0
1440
2880
4320
5760
7200
Time (mins)


pH of MDPB0011 Discharge
pH
7.25
7.20
7.15
7.10
7.05
7.00
6.95
6.90
0
1440
2880
4320
5760
7200
Time (mins)

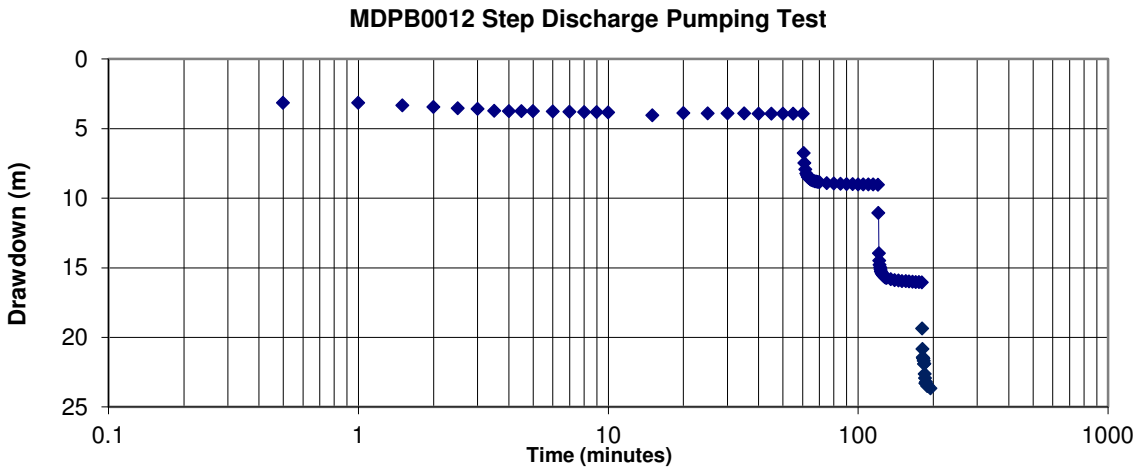

EC at Monitoring Bore MDPZ7450B
Duration of CRT
EC (uS/cm)
1700
1680
1660
1640
1620
1600
1580
1560
1540
1520
1500
-4320
-2880
-1440
0
1440
2880
4320
5760
7200
8640
10080
11520
12960
14400
Time (mins)

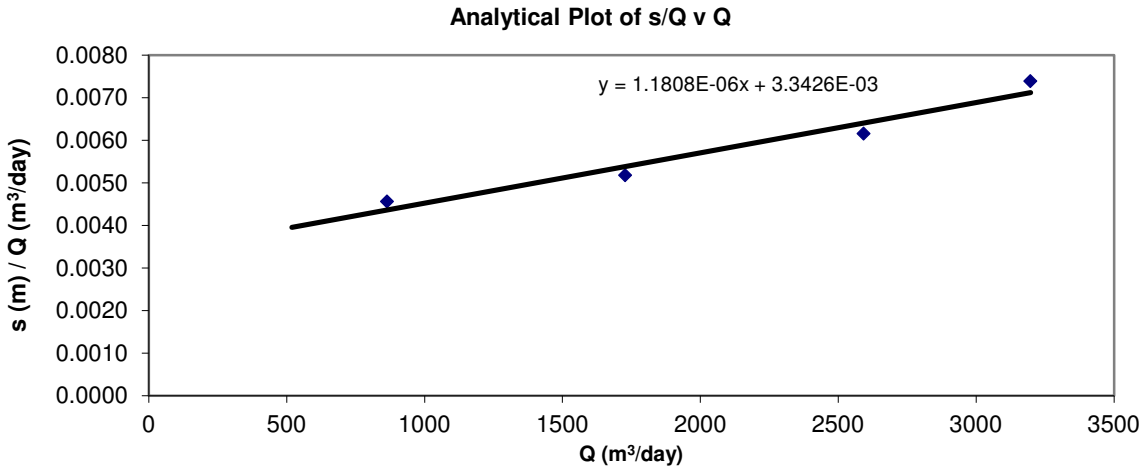




AQ2

MDPB0011 Constant Rate Test Recovery





$s_{w(n)} = BQ_n + CQ^P{}_n$ (Rorabaugh's equation)

Where, B = Intercept with y axis (coefficient of aquifer loss or laminar flow)
C = Gradient (coefficient of turbulent flow loss or apparent well loss)
s = Drawdown in the borehole
P = Value determined using Rorabaugh's method of superposition

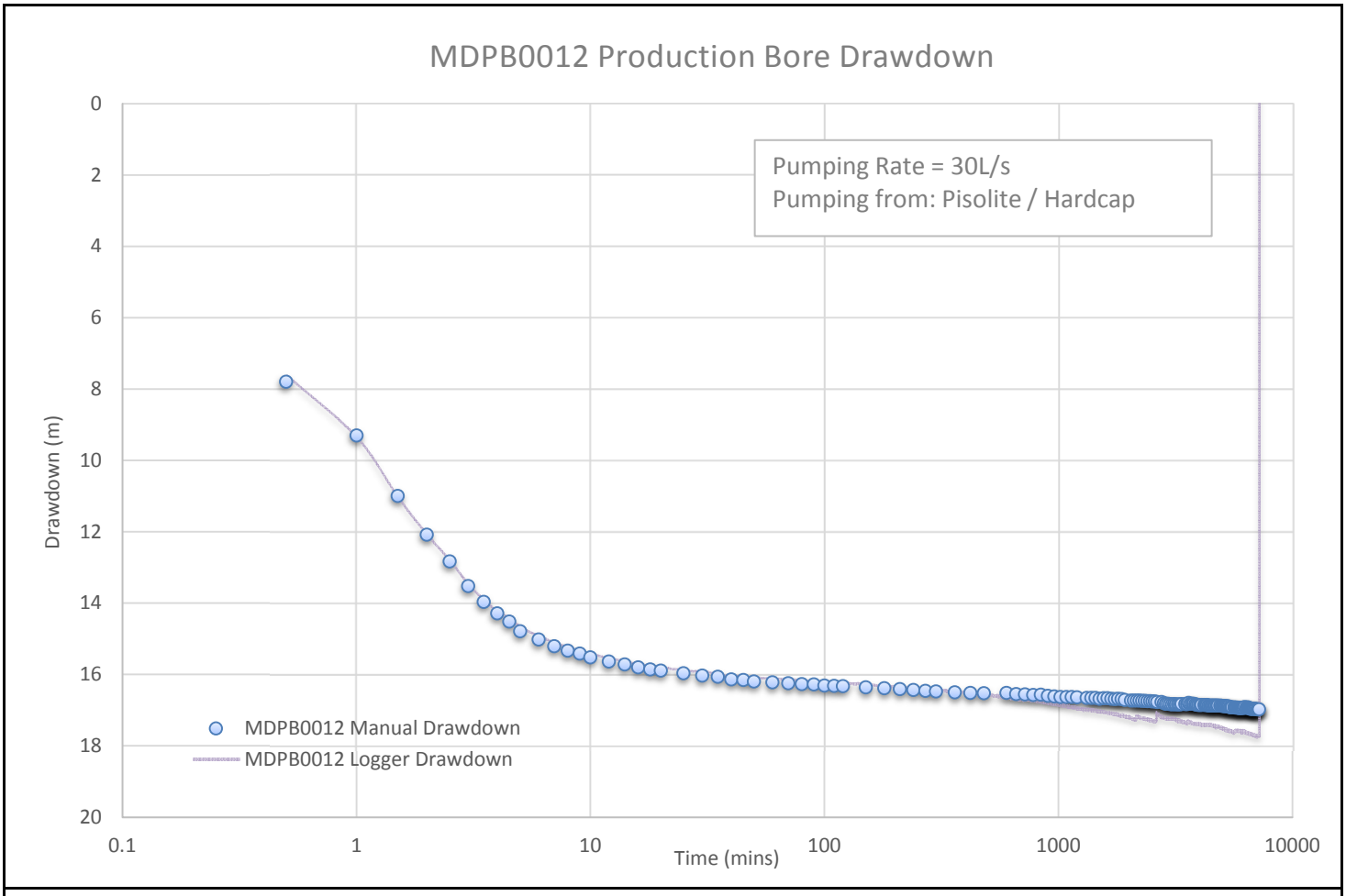
Components of the equation BQ and CQ^2 are termed the aquifer loss and apparent well loss respectively.
They give an indication of the proportion of total drawdown caused by laminar and turbulent flow.

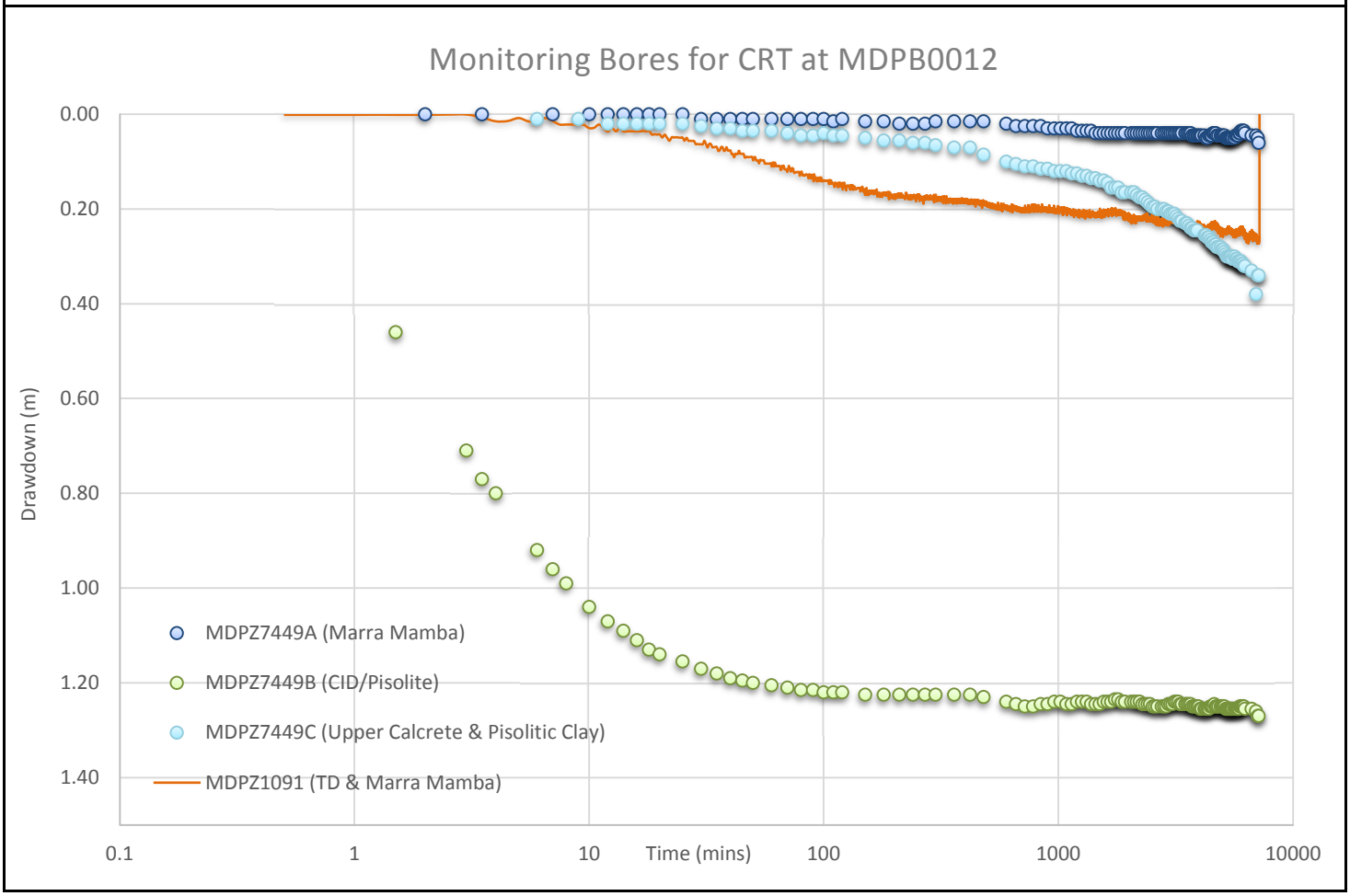
It should be noted:
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2. In aquifers where the flow horizons are vertically anisotropic, changes in bore performance often relate to changes in the rest water level with respect to the primary aquifer horizons.

$Ew = (BQ/(BQ + CQ^P)) \times 100$

Ew or Well Efficiency represents the proportion of drawdown caused by laminar flow

Comparison of Observed and Predicted Drawdowns						
Step (60 min steps)	Discharge (L/s)	Discharge (Q) (m3/d)	Observed Corrected Drawdown (s) (metres)	Predicted Drawdown (metres)	s/Q	Apparent Efficiency (Ew) %
1	10.0	864	3.94	3.77	0.0046	76.62
2	20.0	1728	8.94	9.30	0.0052	62.10
3	30.0	2592	15.94	16.60	0.0061	52.20
4	37.0	3197	23.60	22.75	0.0074	46.96

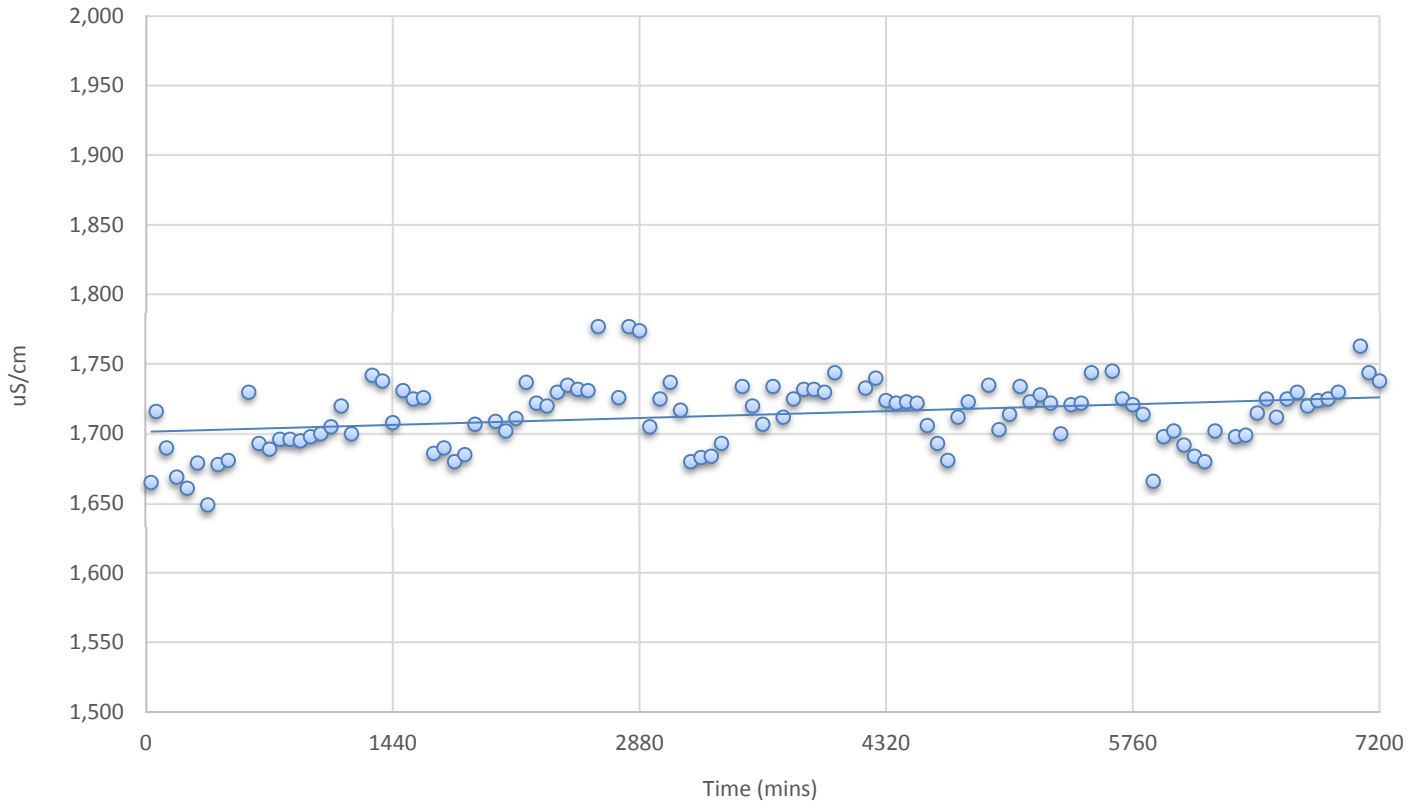


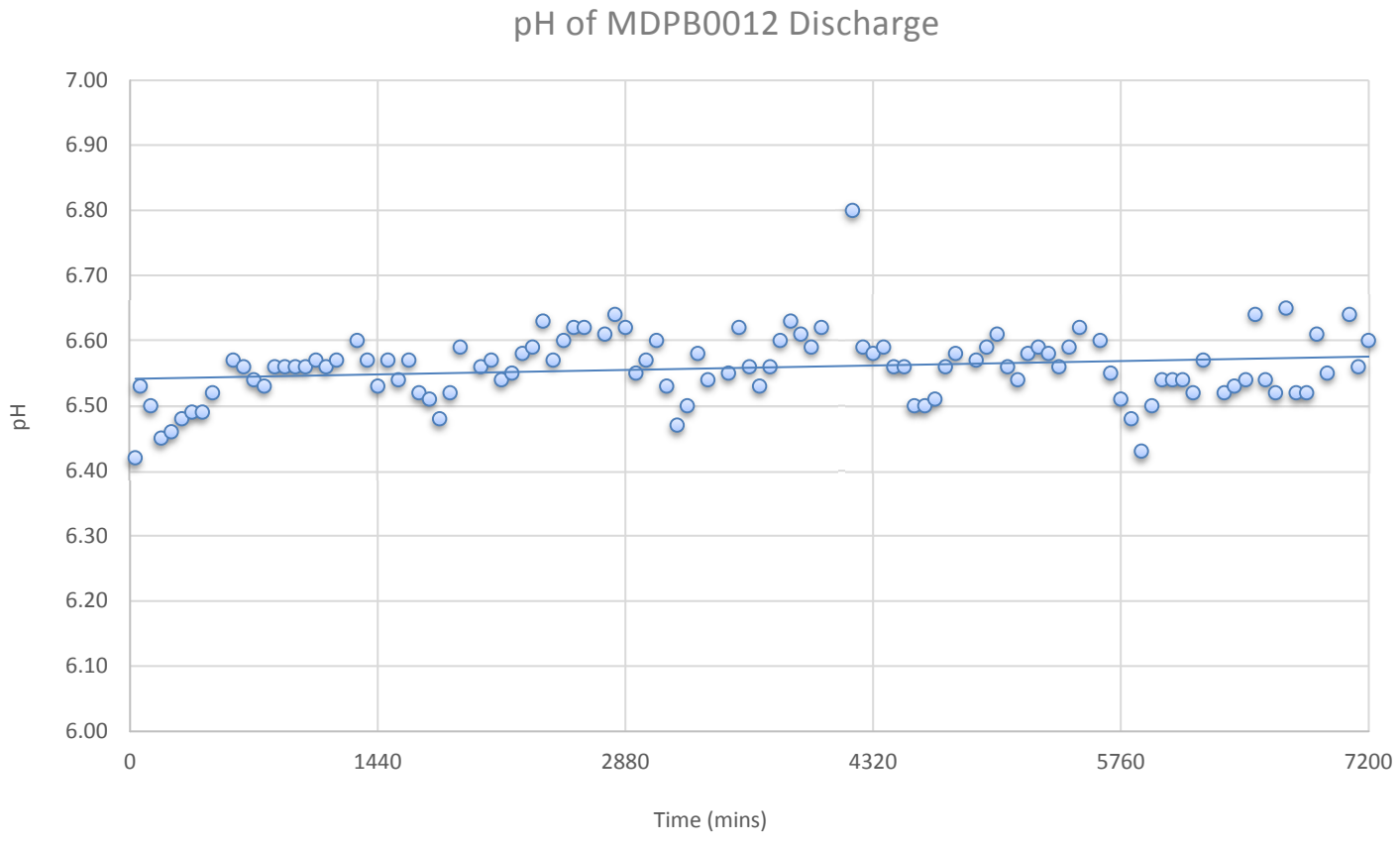


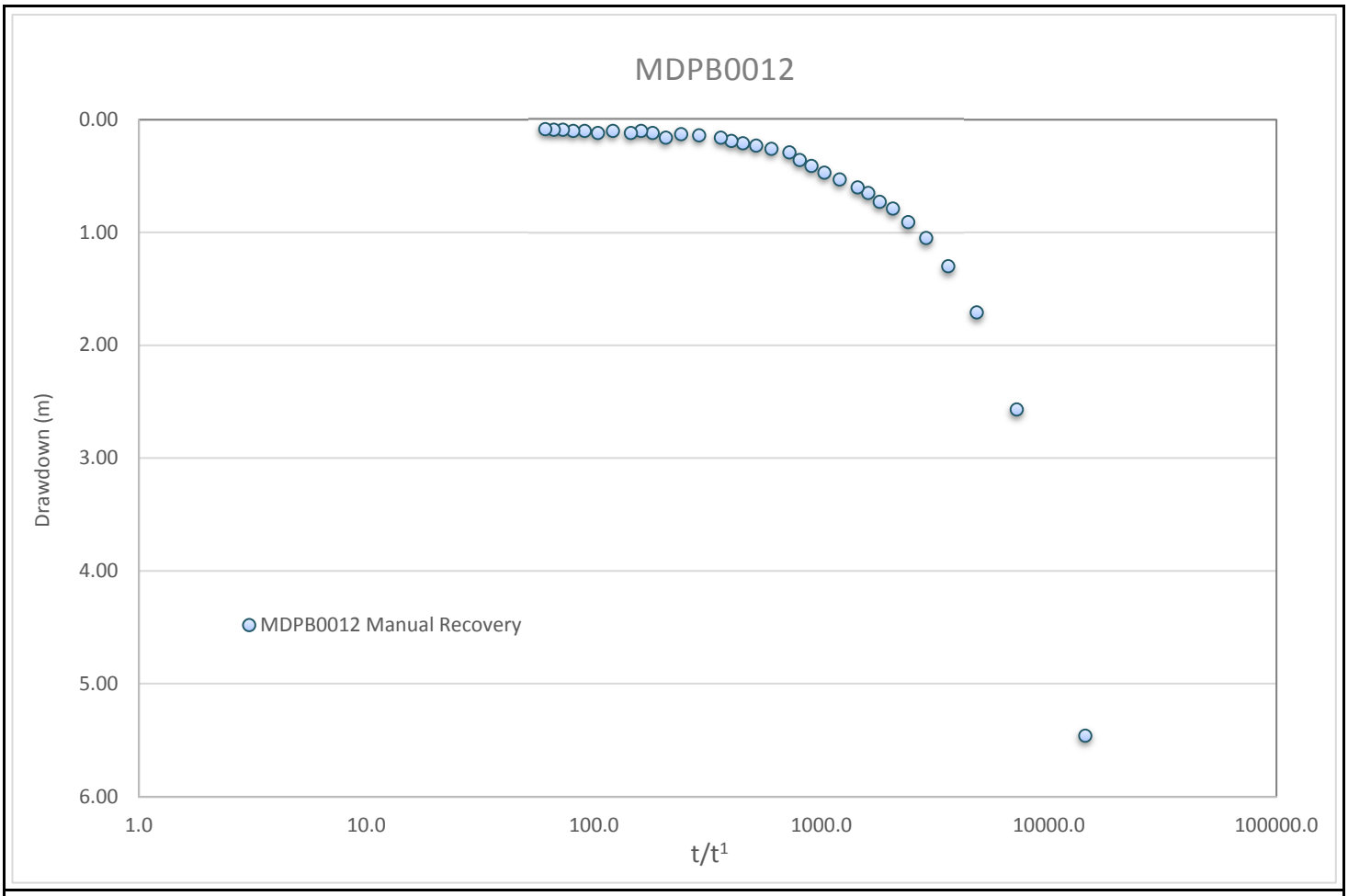
AQ2

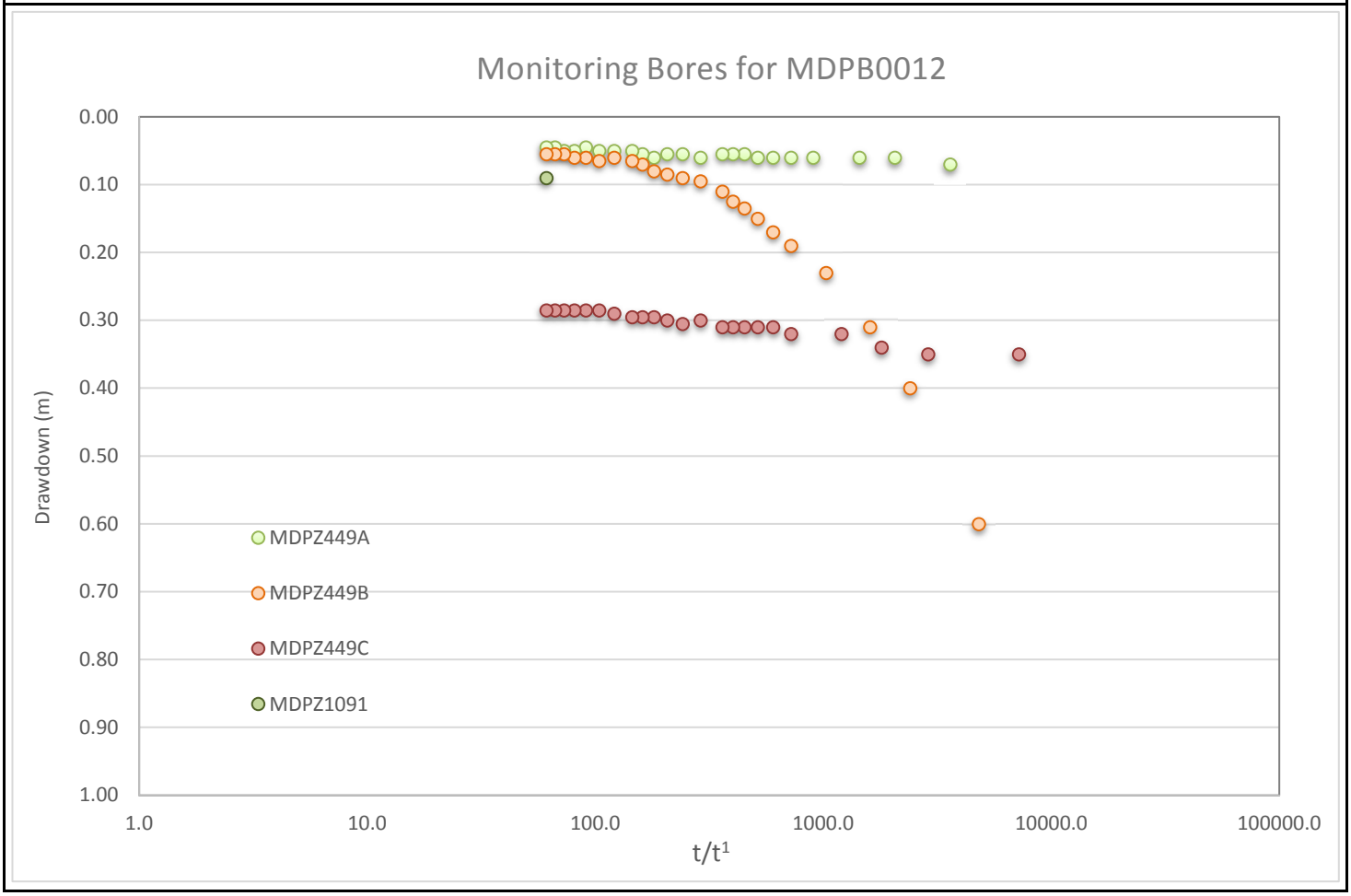
MDPB0012 Constant Rate Test Drawdown

F:\171\2.TECH\Test Pumping\MDPB0012\[MDPB0012 CRT Manual 24.09.19 11.00AM.xlsm]Report Figure


EC of MDPB0012 Discharge
uS/cm
2,000
1,950
1,900
1,850
1,800
1,750
1,700
1,650
1,600
1,550
1,500
0
1440
2880
4320
5760
7200
Time (mins)

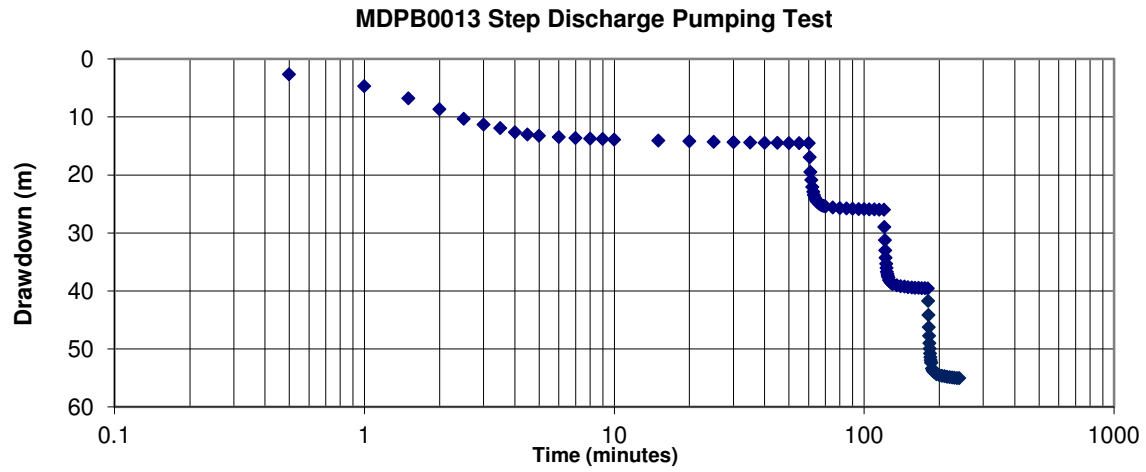

pH of MDPB0012 Discharge
pH
7.00
6.90
6.80
6.70
6.60
6.50
6.40
6.30
6.20
6.10
6.00
0
1440
2880
4320
5760
7200
Time (mins)

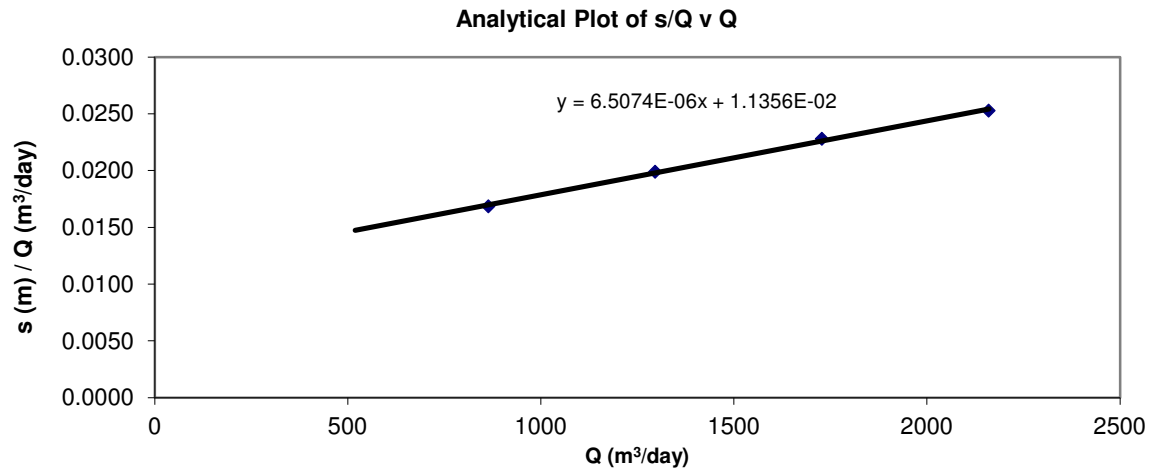




AQ2

MDPB0012 Constant Rate Test Recovery





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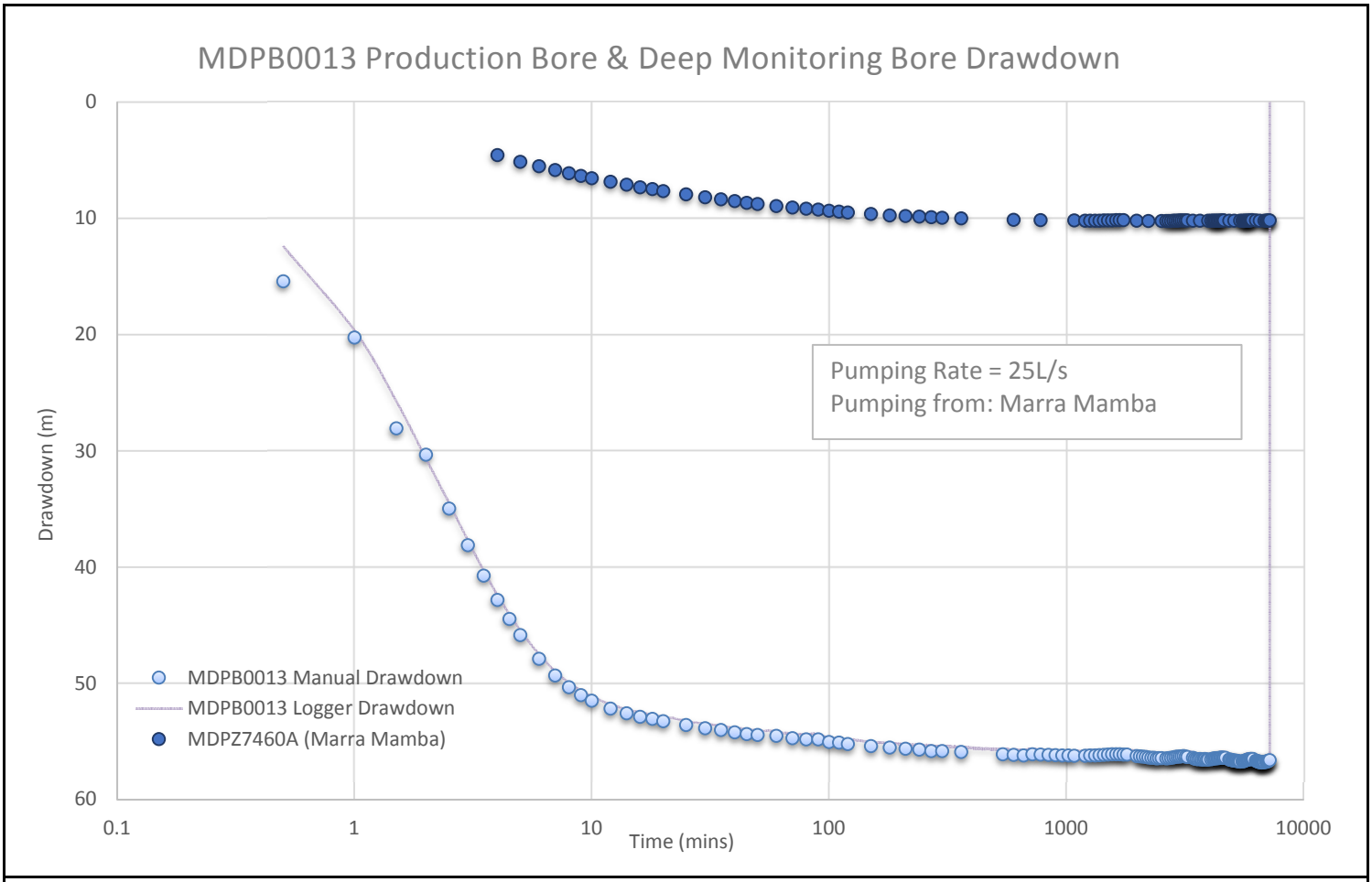
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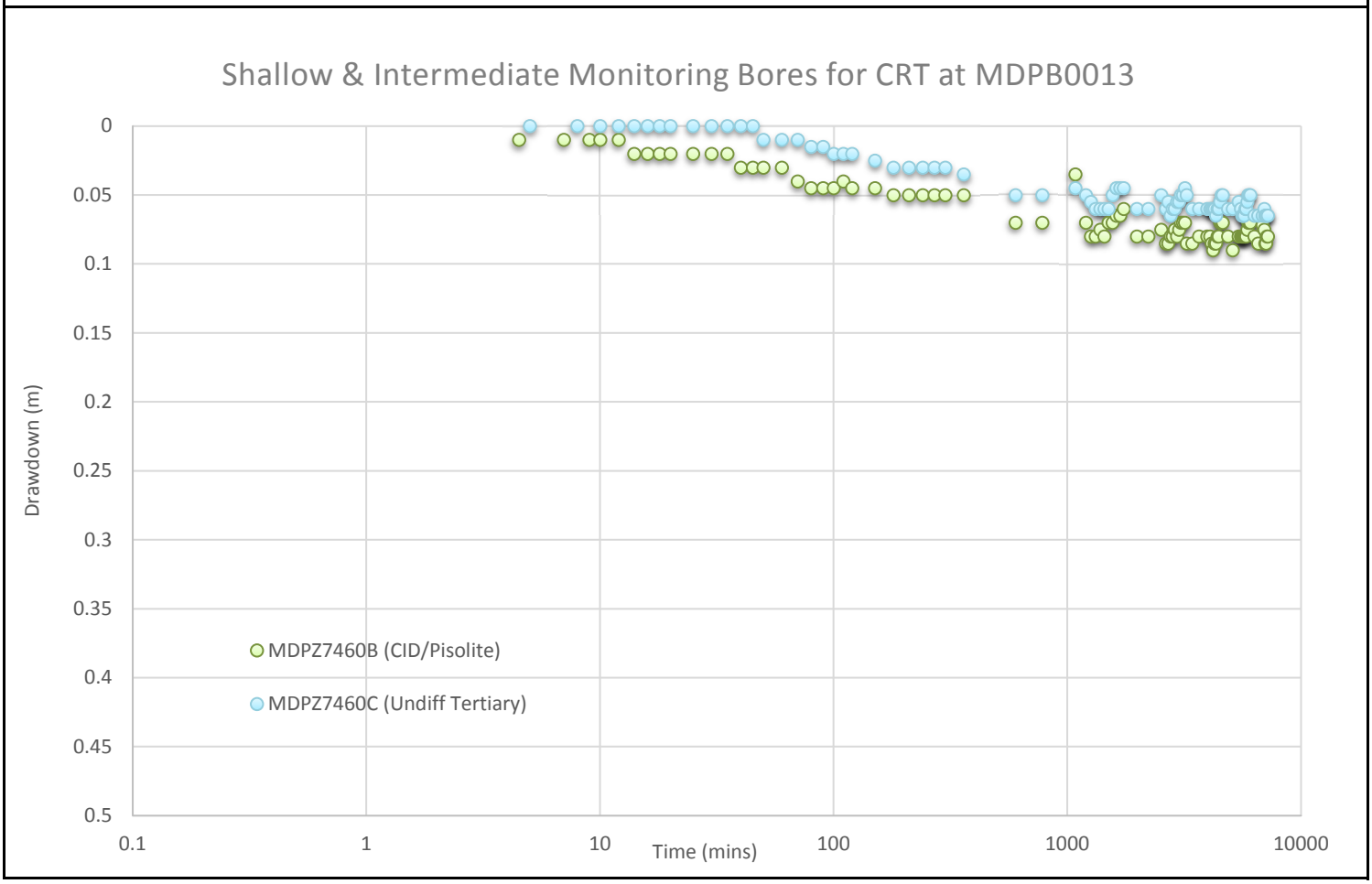
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Step (60 min steps)	Discharge (L/s)	Discharge (Q) (m3/d)	Observed Corrected Drawdown (s) (metres)	Predicted Drawdown (metres)	s/Q	Apparent Efficiency (Ew) %
1	10.0	864	14.57	14.67	0.0169	66.89
2	15.0	1296	25.77	25.65	0.0199	57.38
3	20.0	1728	39.37	39.05	0.0228	50.25
4	25.0	2160	54.57	54.89	0.0253	44.69

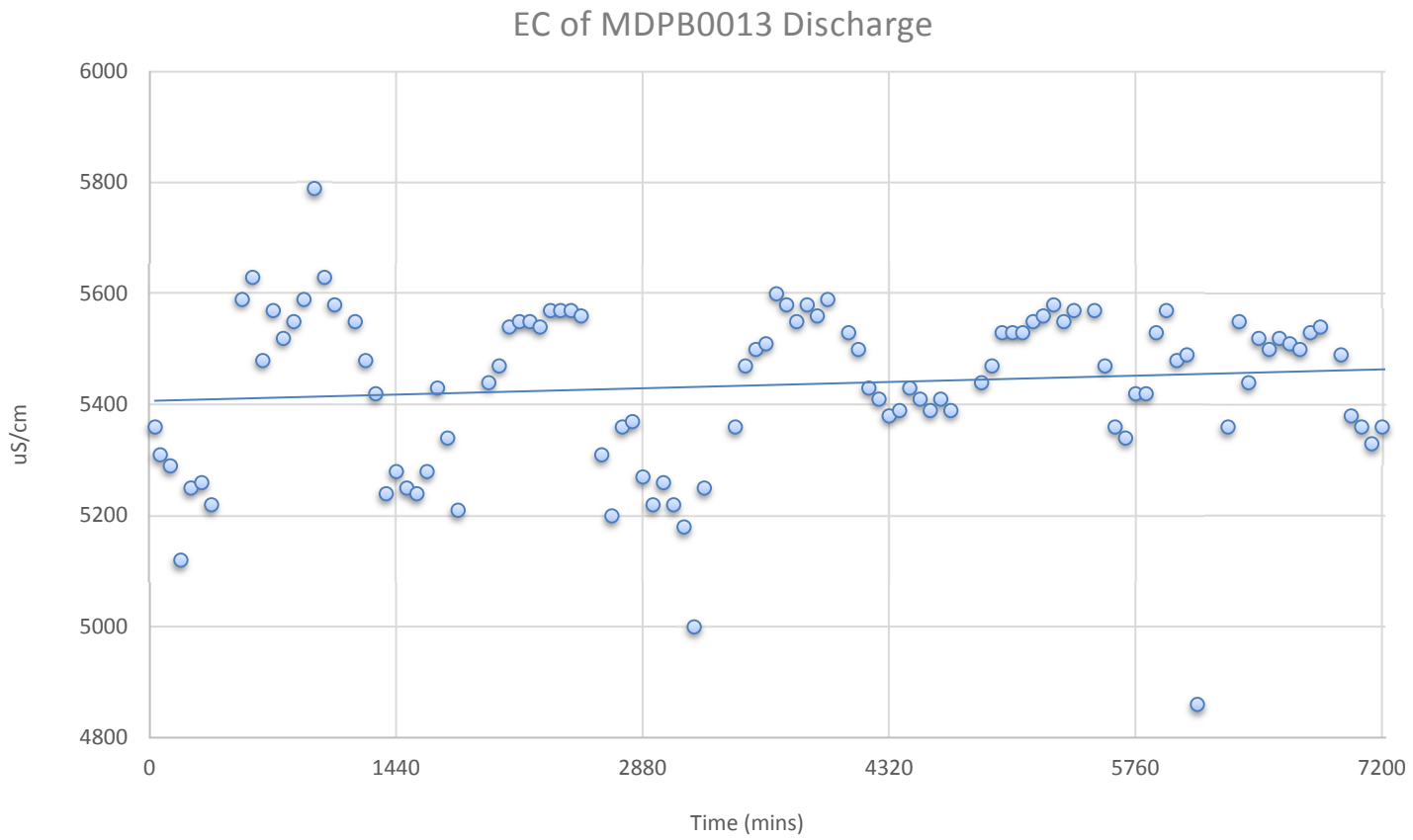


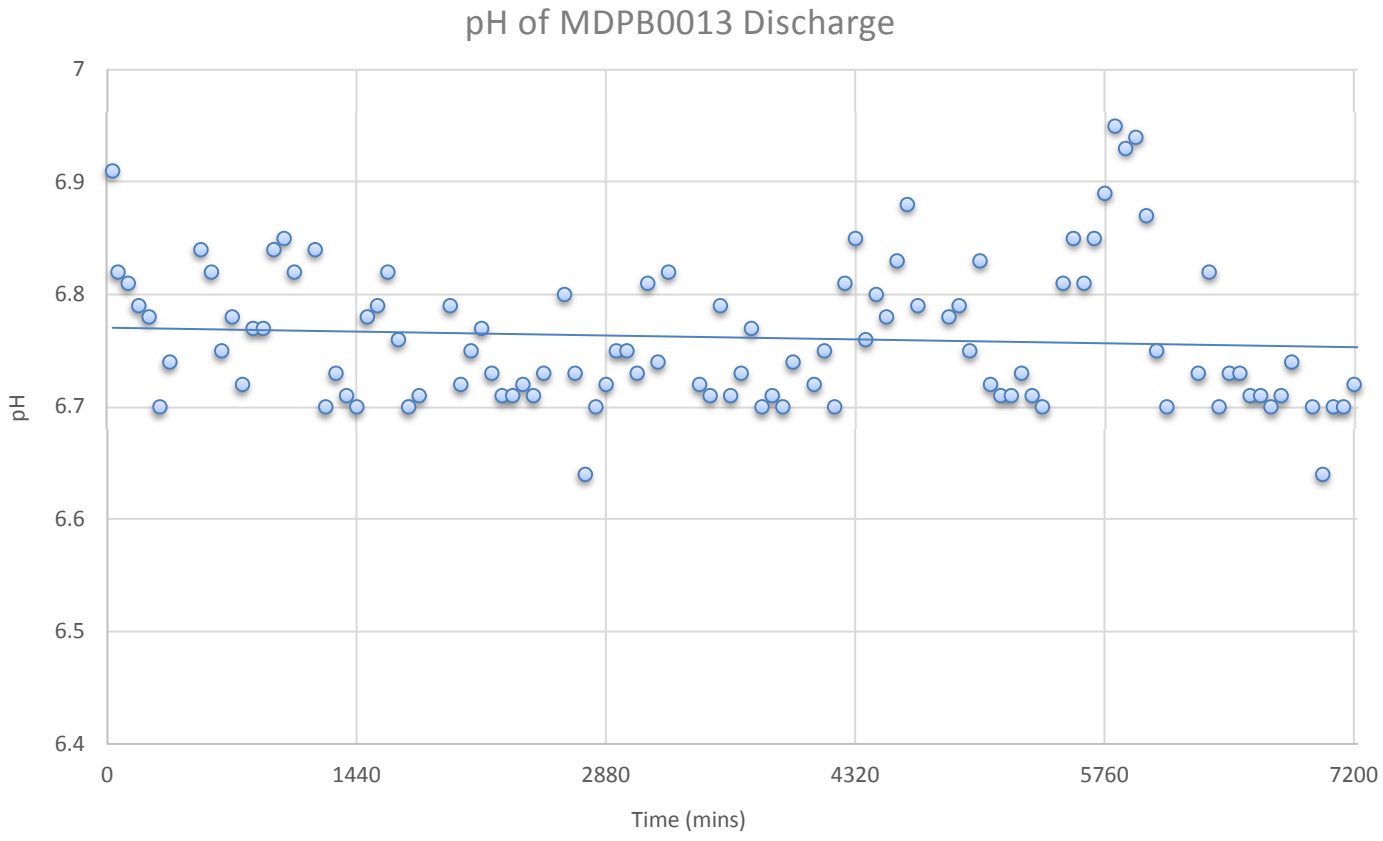


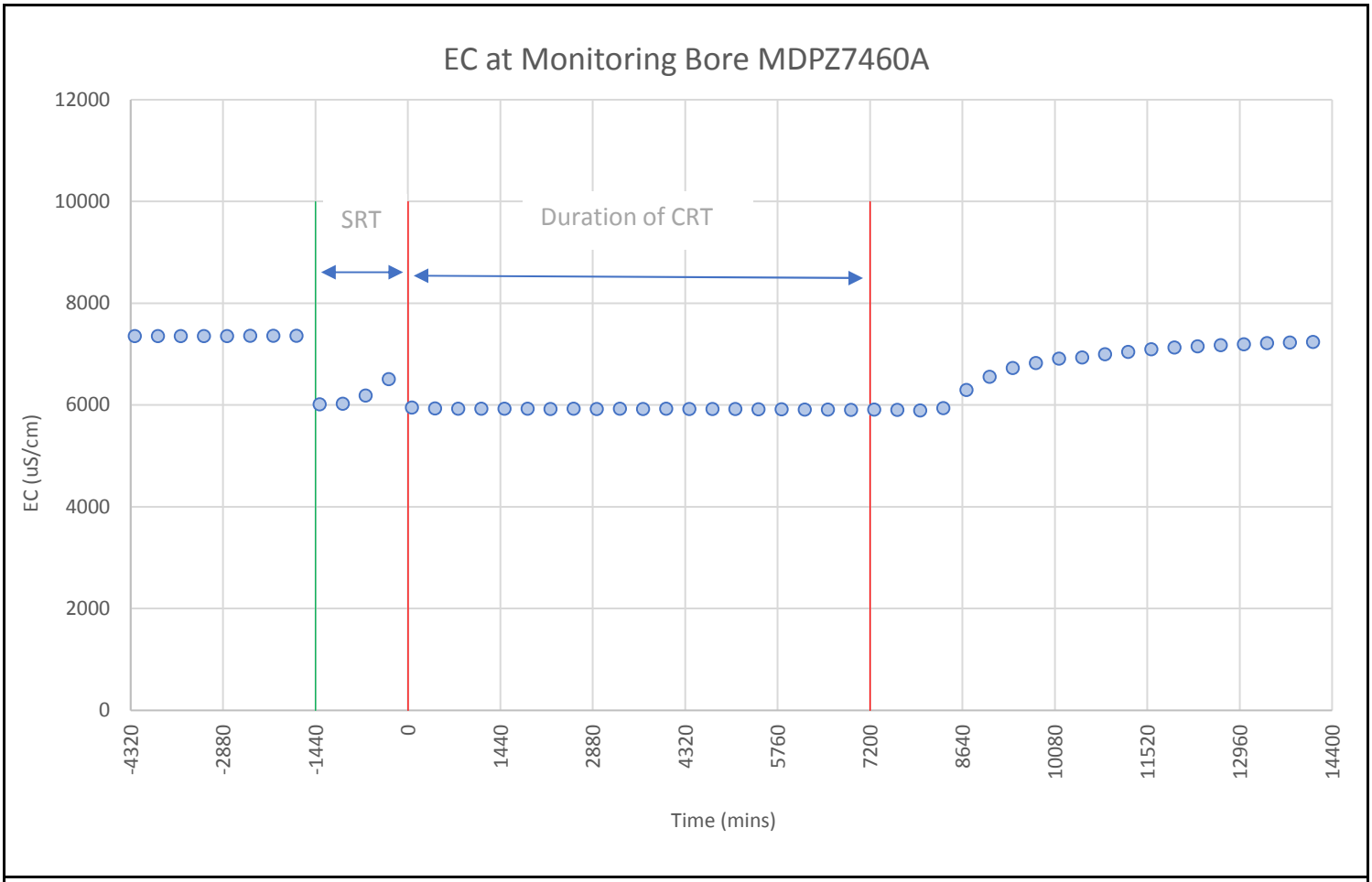
AQ2

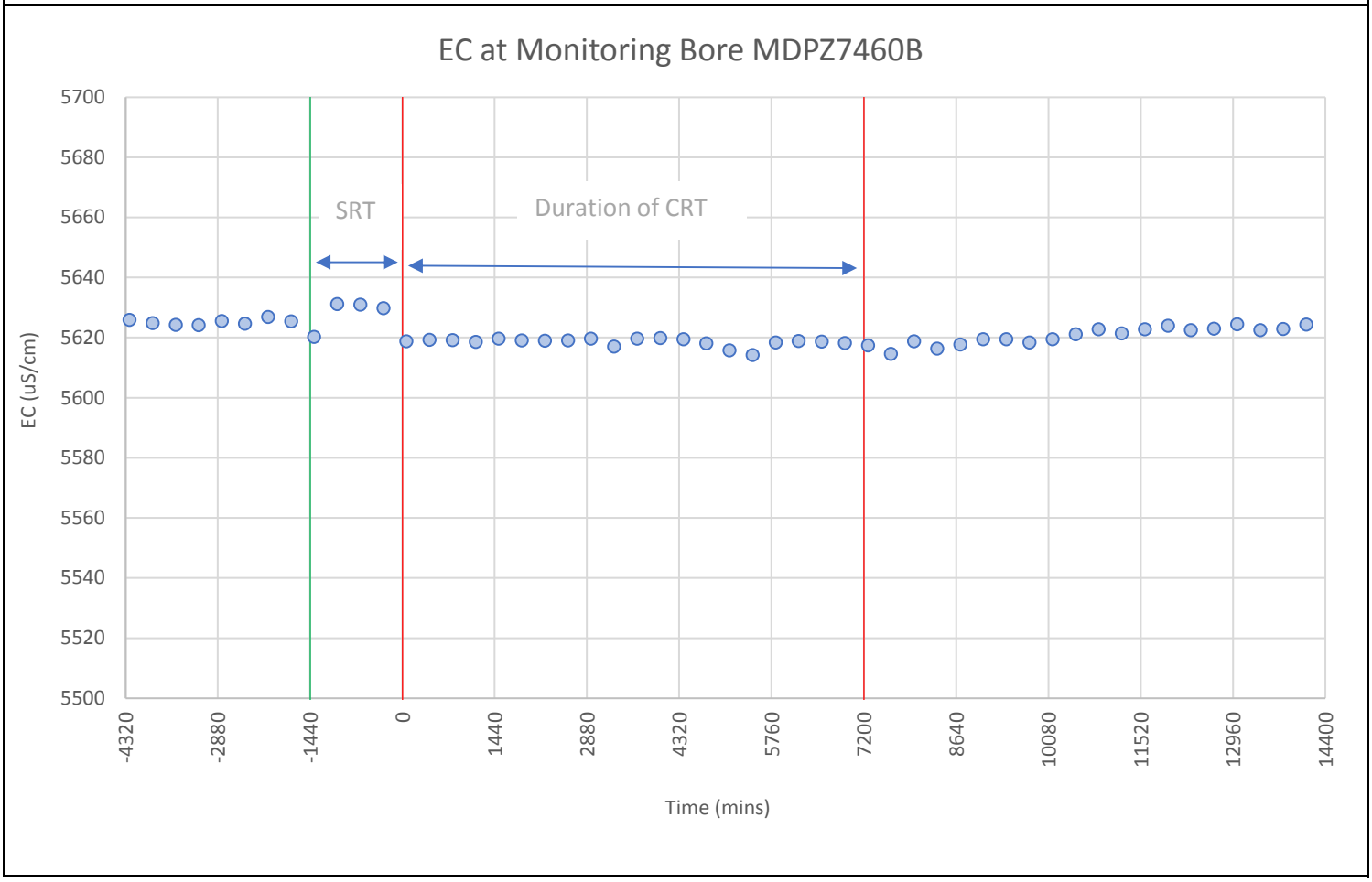
MDPB0013 Constant Rate Test Drawdown

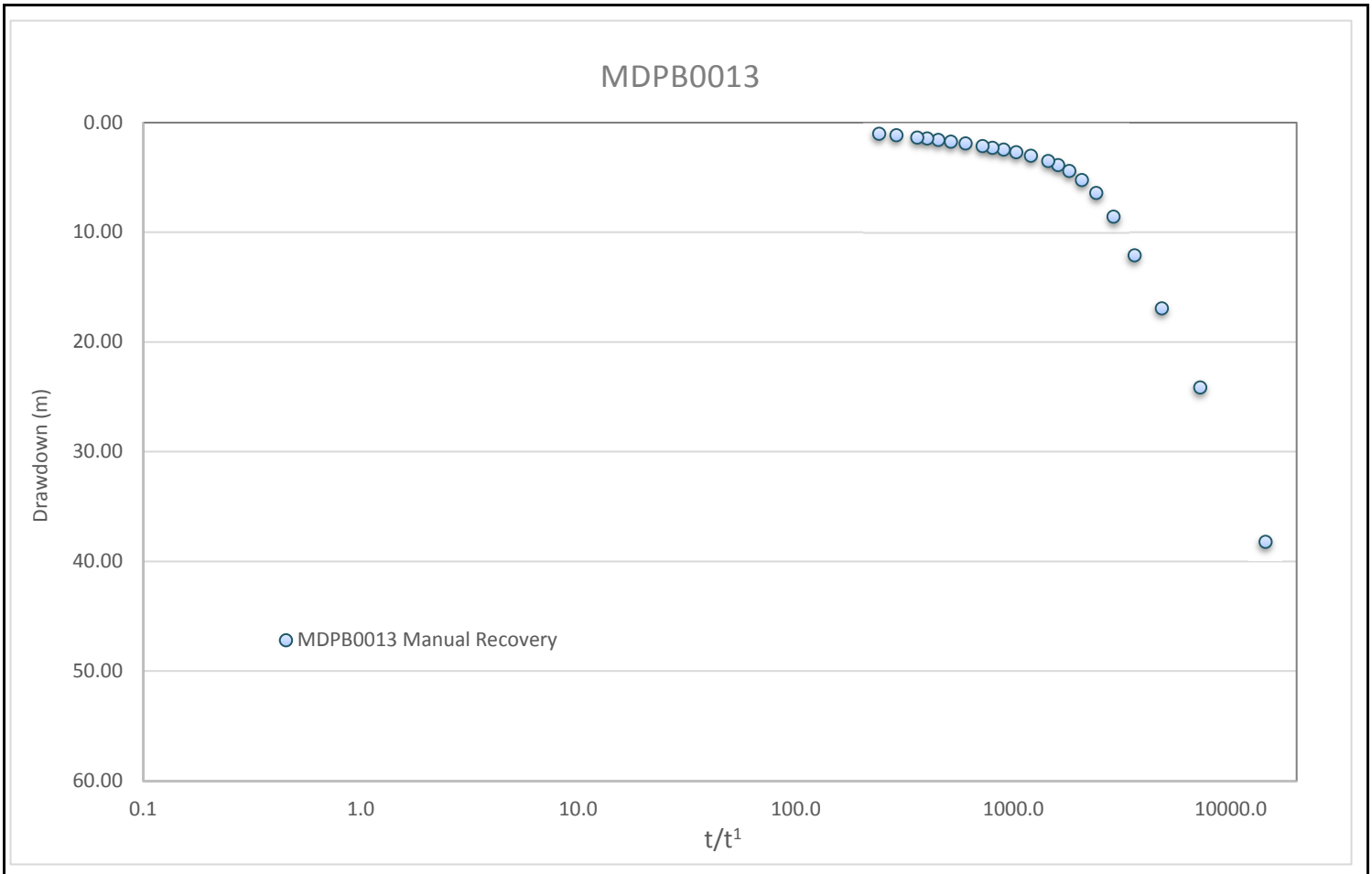
F:\171\2.TECH\Test Pumping\MDPB0013\[MDPB0013 Report Figure.xlsx]Report Figure

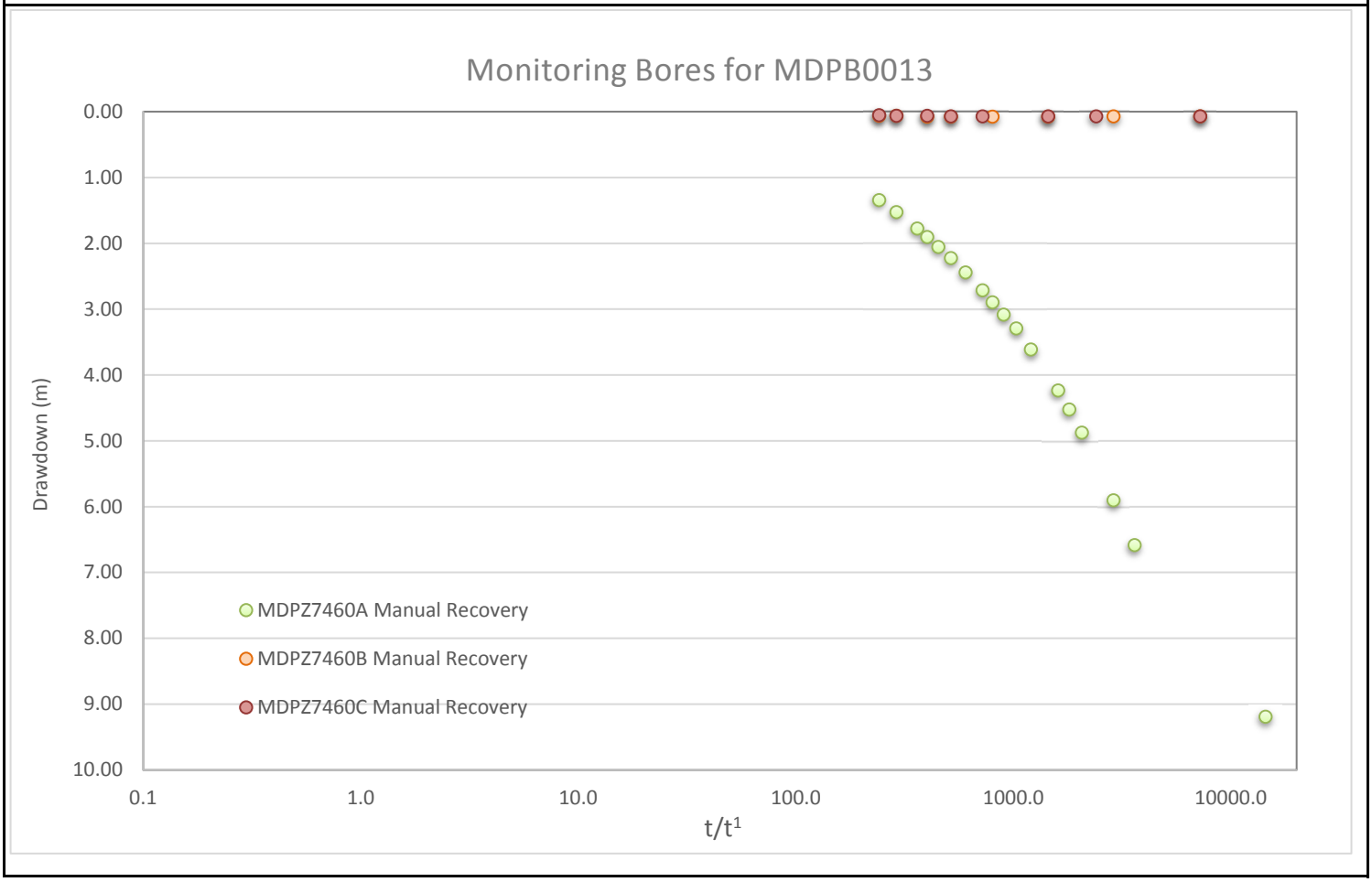

EC of MDPB0013 Discharge
uS/cm
6000
5800
5600
5400
5200
5000
4800
0
1440
2880
4320
5760
7200
Time (mins)


pH of MDPB0013 Discharge
pH
7
6.9
6.8
6.7
6.6
6.5
6.4
0
1440
2880
4320
5760
7200
Time (mins)


EC at Monitoring Bore MDPZ7460A
12000
10000
8000
6000
4000
2000
0
EC (uS/cm)
SRT
Duration of CRT
-4320
-2880
-1440
0
1440
2880
4320
5760
7200
8640
10080
11520
12960
14400
Time (mins)

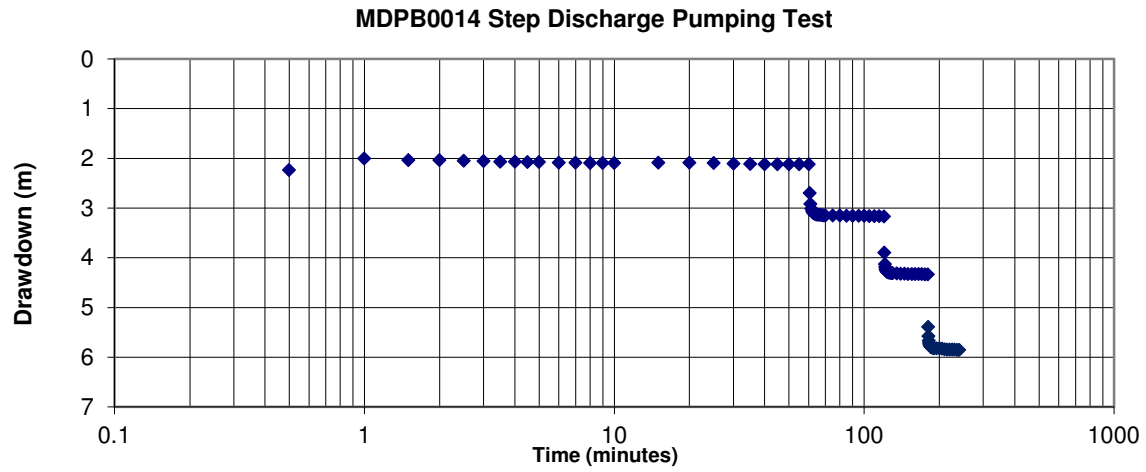

EC at Monitoring Bore MDPZ7460B
5700
5680
5660
5640
5620
5600
5580
5560
5540
5520
5500
EC (uS/cm)
SRT
Duration of CRT
-4320
-2880
-1440
0
1440
2880
4320
5760
7200
8640
10080
11520
12960
14400
Time (mins)

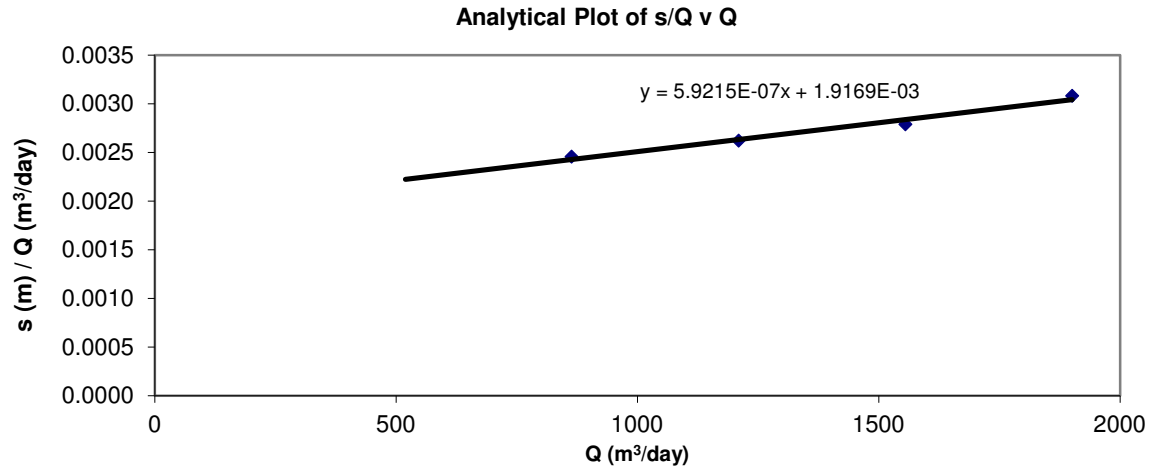




AQ2

MDPB0013 Constant Rate Test Recovery





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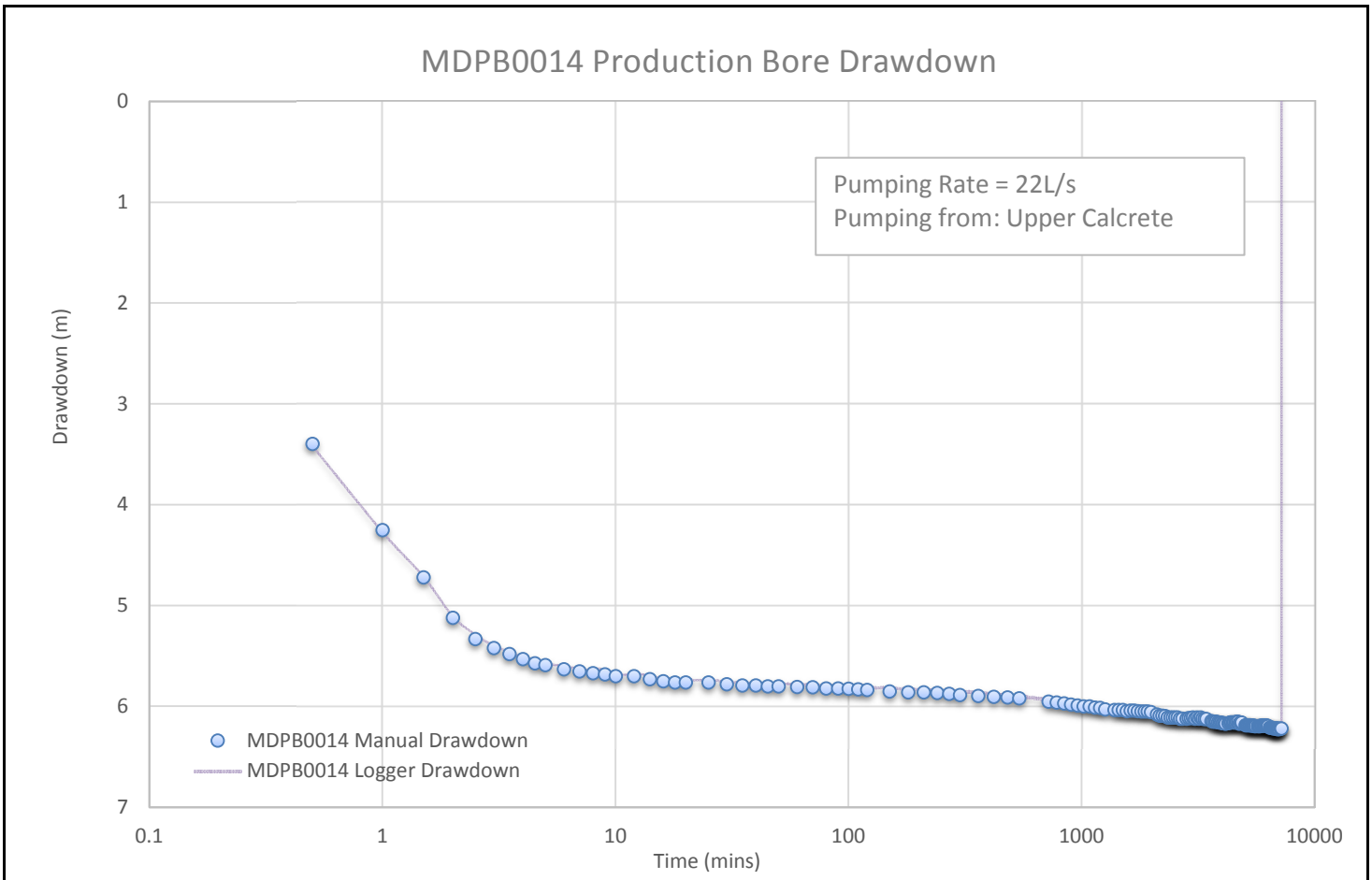
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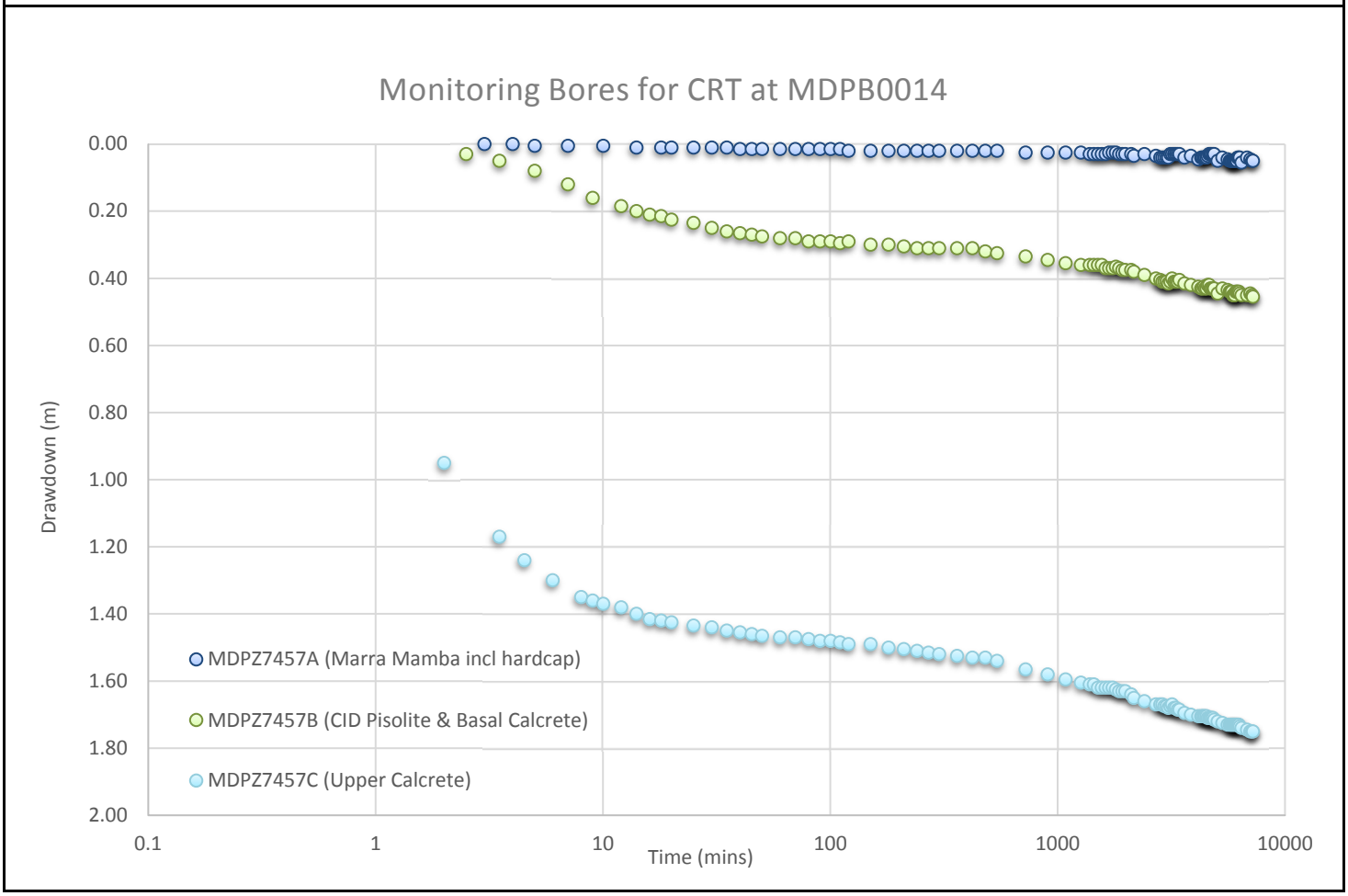
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2	14.0	1210	3.17	3.19	0.0026	72.80
3	18.0	1555	4.34	4.41	0.0028	67.55
4	22.0	1901	5.86	5.78	0.0031	63.00

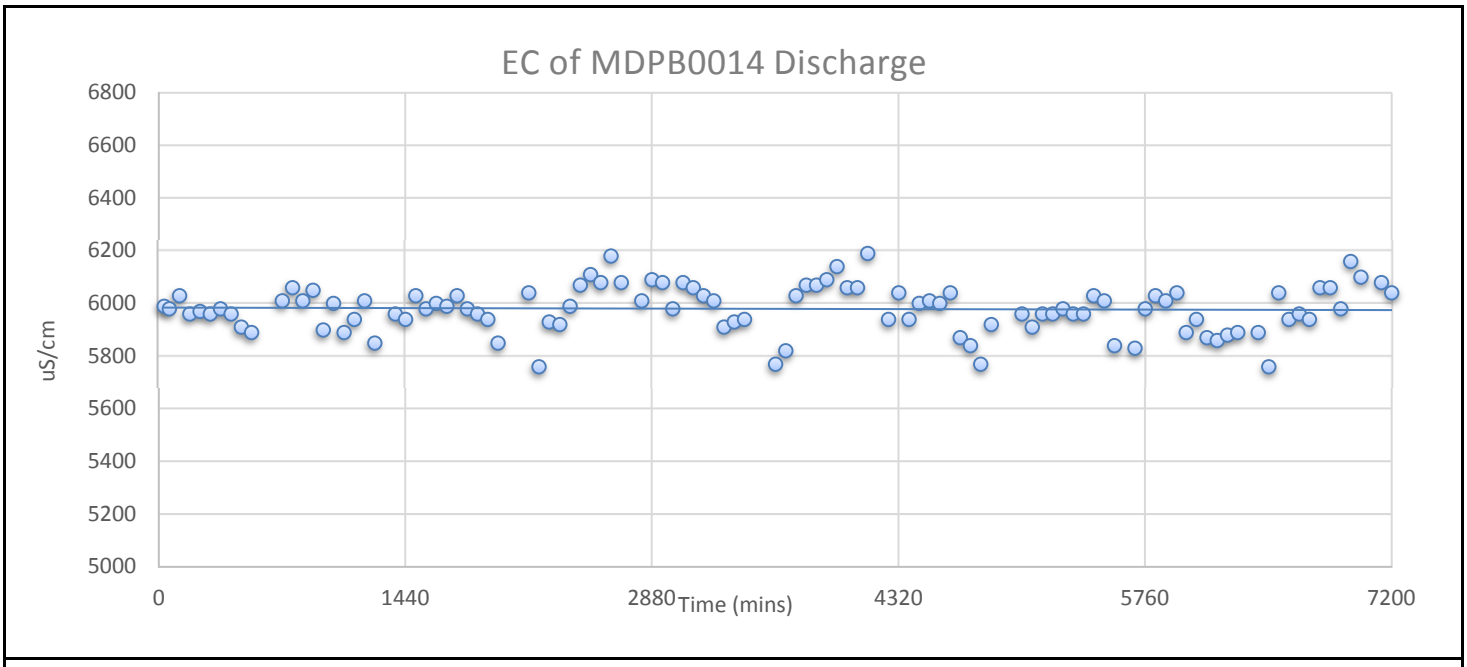


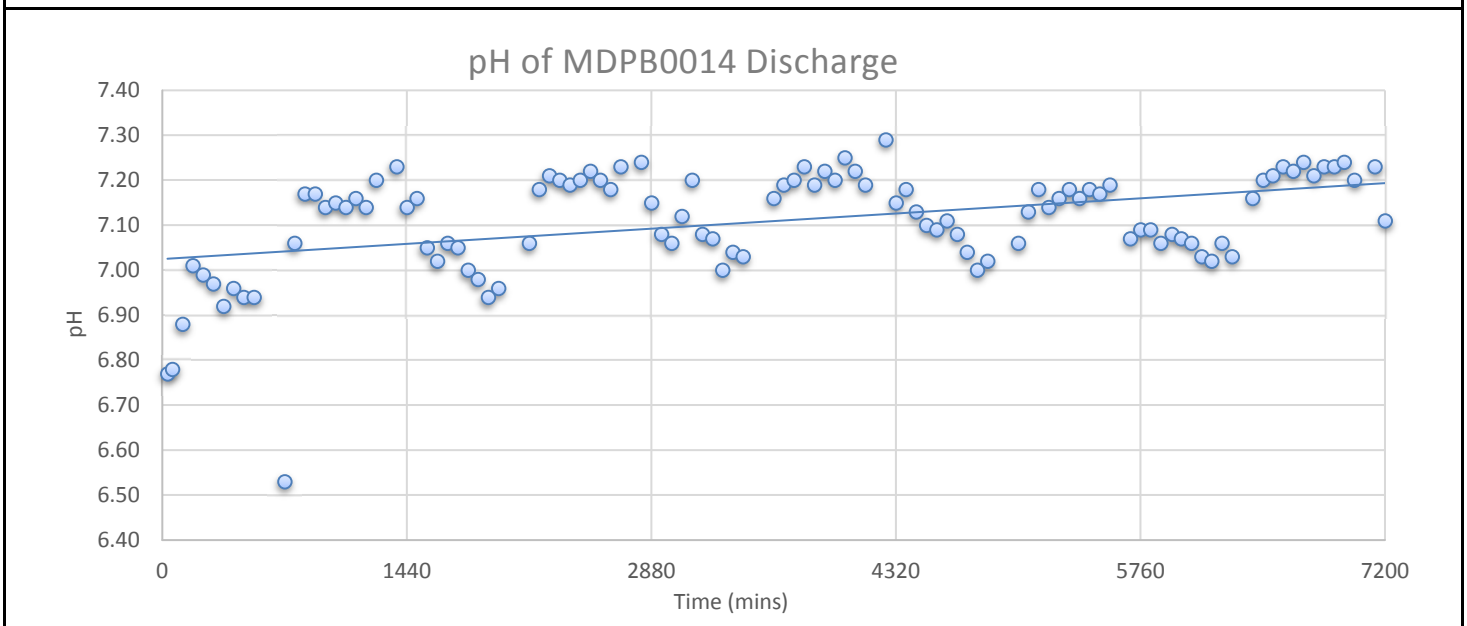


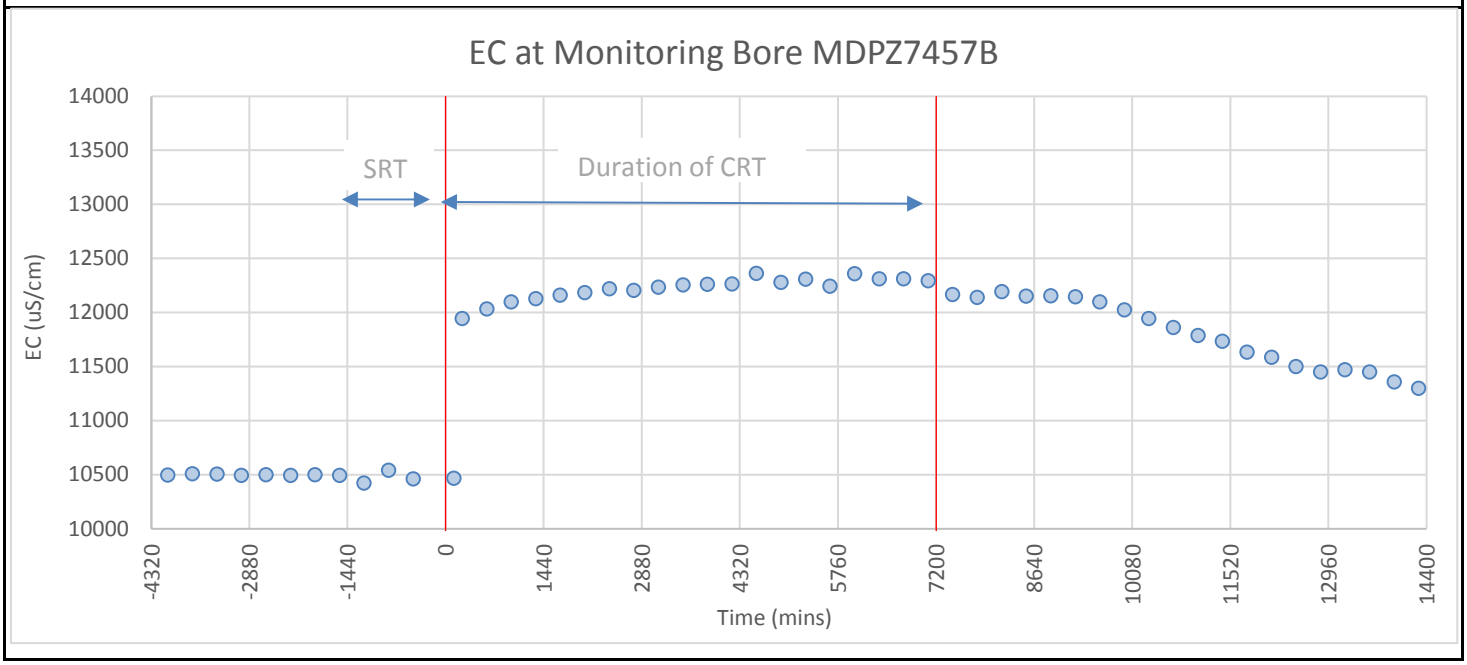
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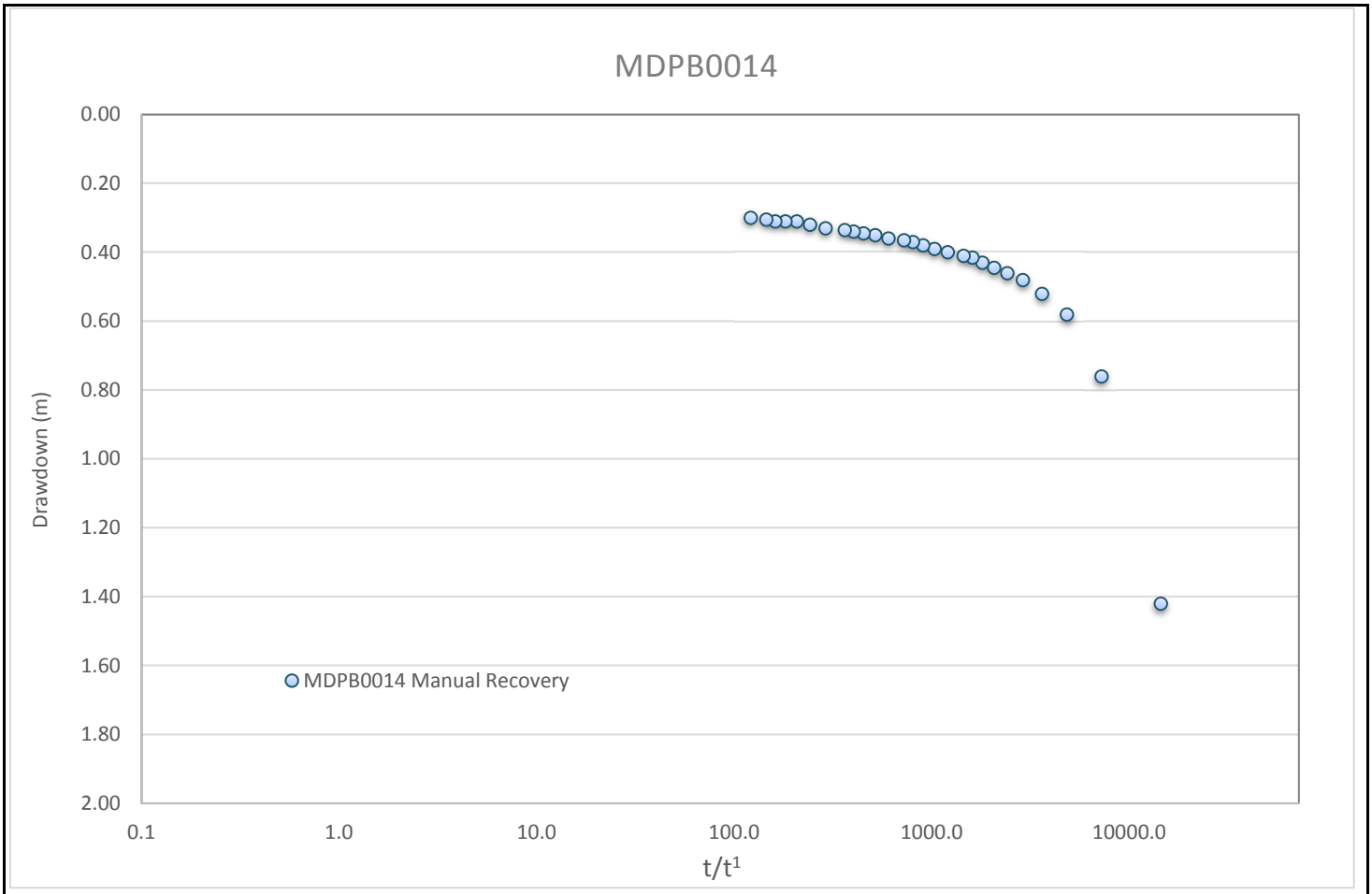
MDPB0014 Constant Rate Test Drawdown

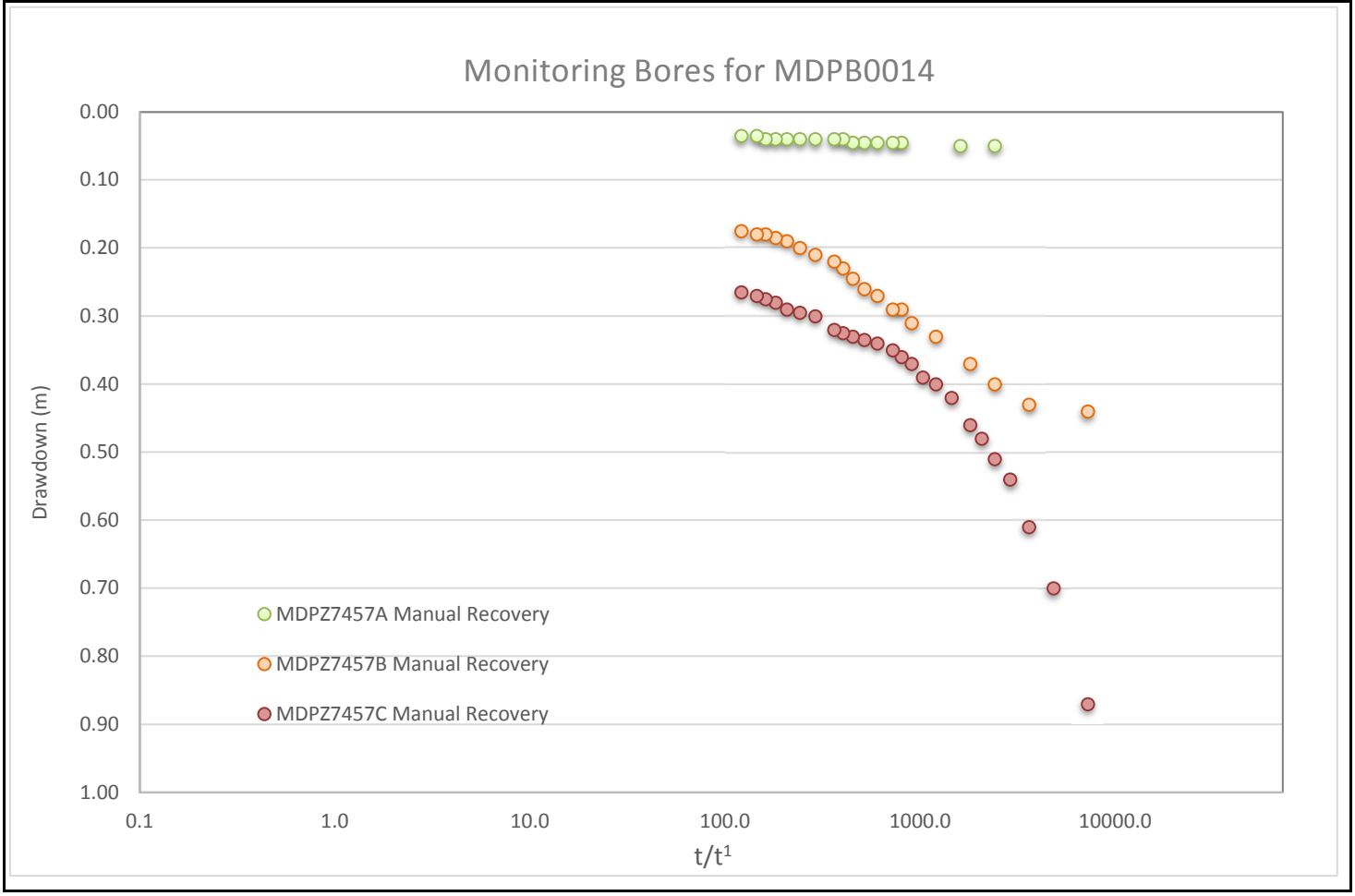
F:\171\2.TECH\Test Pumping\MDPB0014\[MDPB0014 CRT Manual 09.10.19 9am.xlsm]Report Figure


EC of MDPB0014 Discharge
uS/cm
6800
6600
6400
6200
6000
5800
5600
5400
5200
5000
0
1440
2880
4320
5760
7200
Time (mins)


pH of MDPB0014 Discharge
pH
7.40
7.30
7.20
7.10
7.00
6.90
6.80
6.70
6.60
6.50
6.40
0
1440
2880
4320
5760
7200
Time (mins)

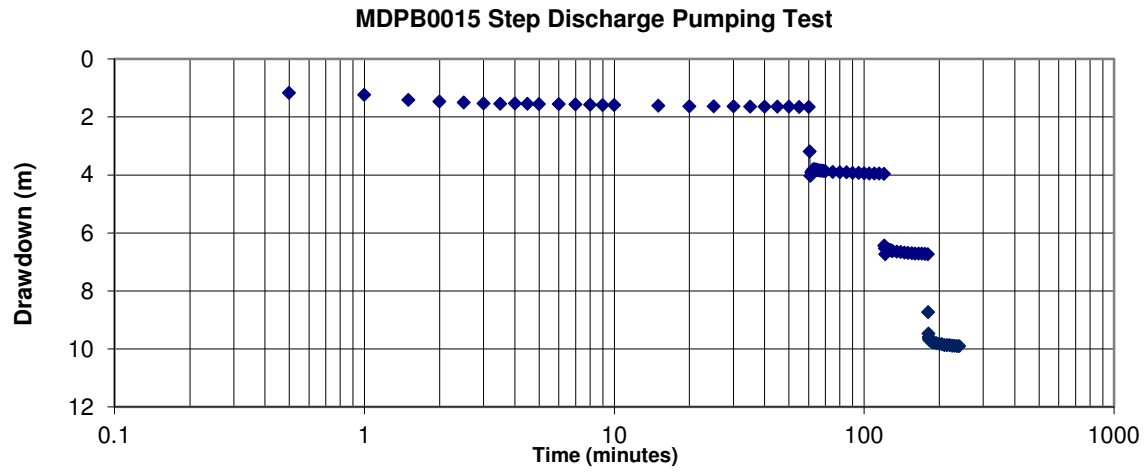

EC at Monitoring Bore MDPZ7457B
EC (uS/cm)
14000
13500
13000
12500
12000
11500
11000
10500
10000
SRT
Duration of CRT
-4320
-2880
-1440
0
1440
2880
4320
5760
7200
8640
10080
11520
12960
14400
Time (mins)

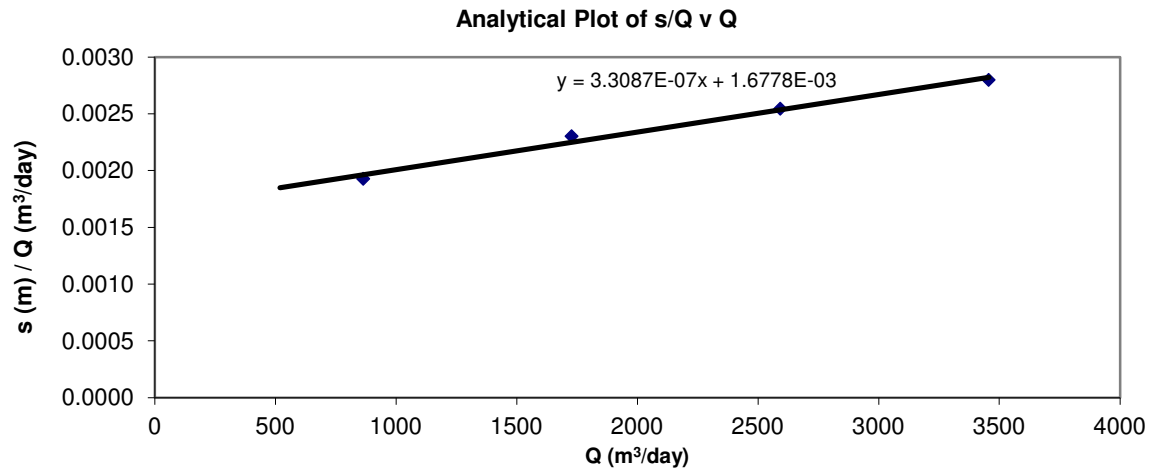




AQ2

MDPB0014 Constant Rate Test Recovery





$s_{w(n)} = BQ_n + CQ^P{}_n$ (Rorabaugh's equation)

Where, B = Intercept with y axis (coefficient of aquifer loss or laminar flow)
C = Gradient (coefficient of turbulent flow loss or apparent well loss)
s = Drawdown in the borehole
P = Value determined using Rorabaugh's method of superposition

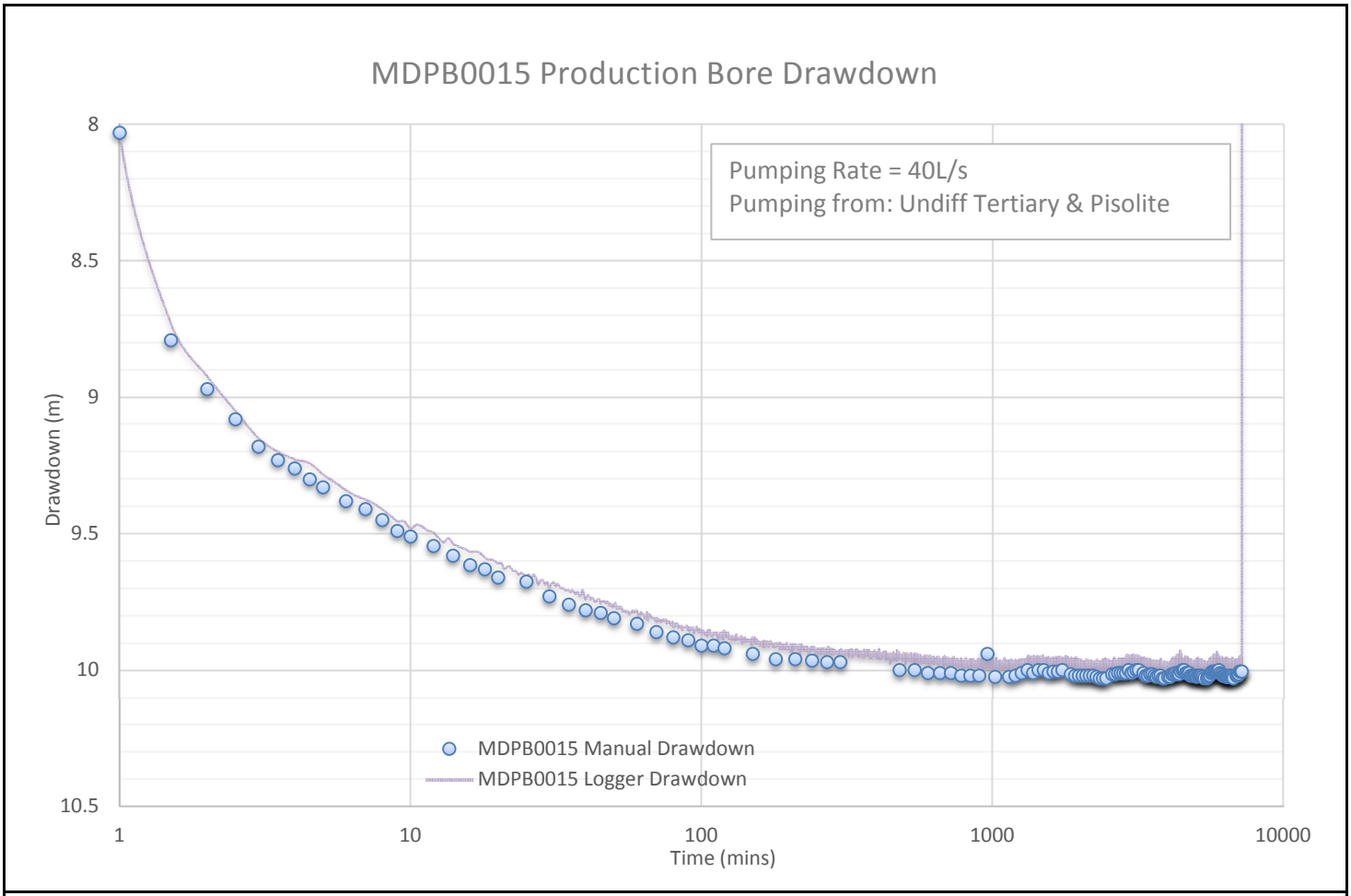
Components of the equation BQ and CQ^2 are termed the aquifer loss and apparent well loss respectively.
They give an indication of the proportion of total drawdown caused by laminar and turbulent flow.

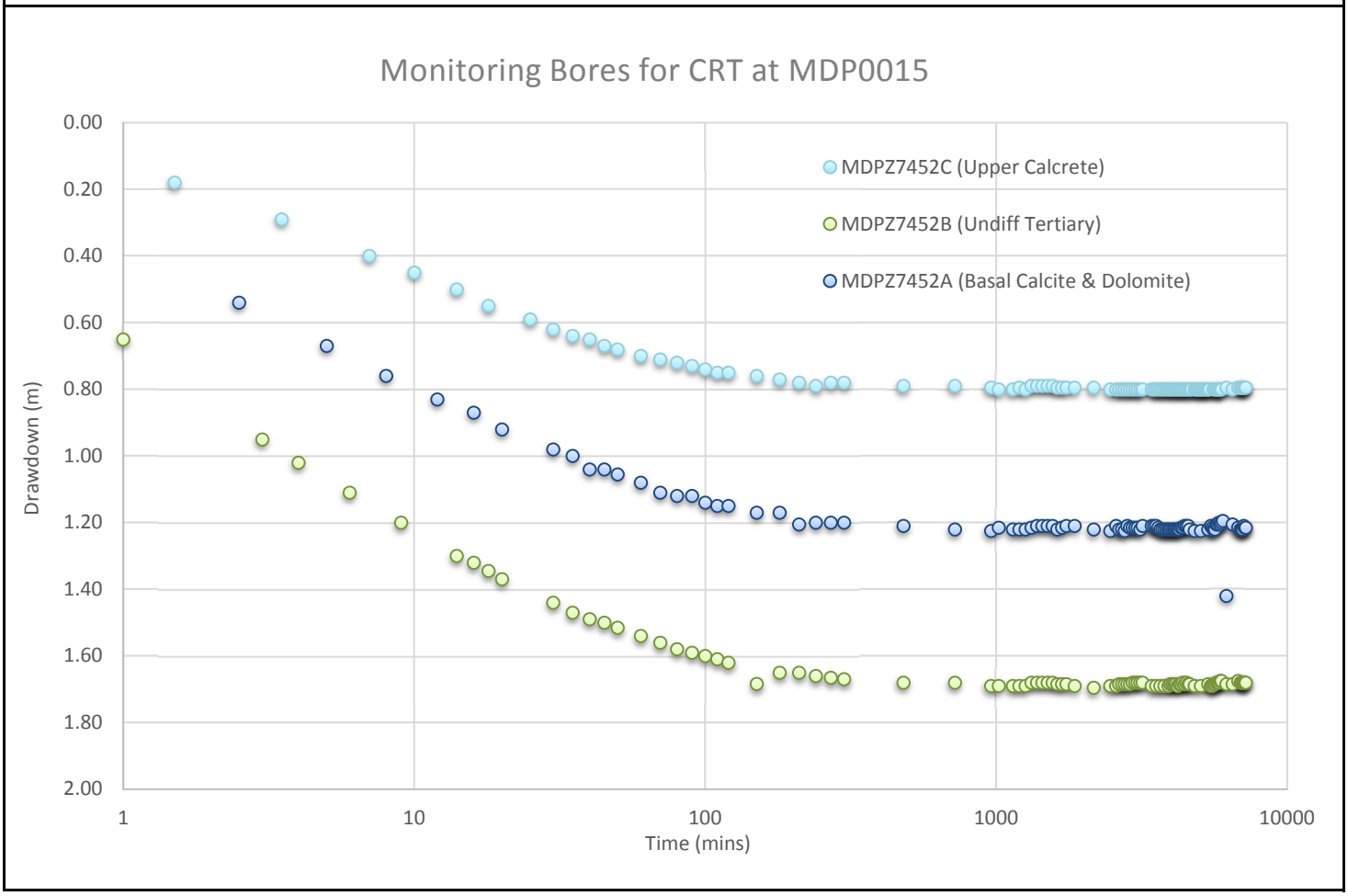
It should be noted:
1. In thin or fissured aquifers large components of well loss are due to high flow velocities in the aquifer rather than inefficient bore design. Therefore, the term "apparent well loss" is better than well loss.
2. In aquifers where the flow horizons are vertically anisotropic, changes in bore performance often relate to changes in the rest water level with respect to the primary aquifer horizons.

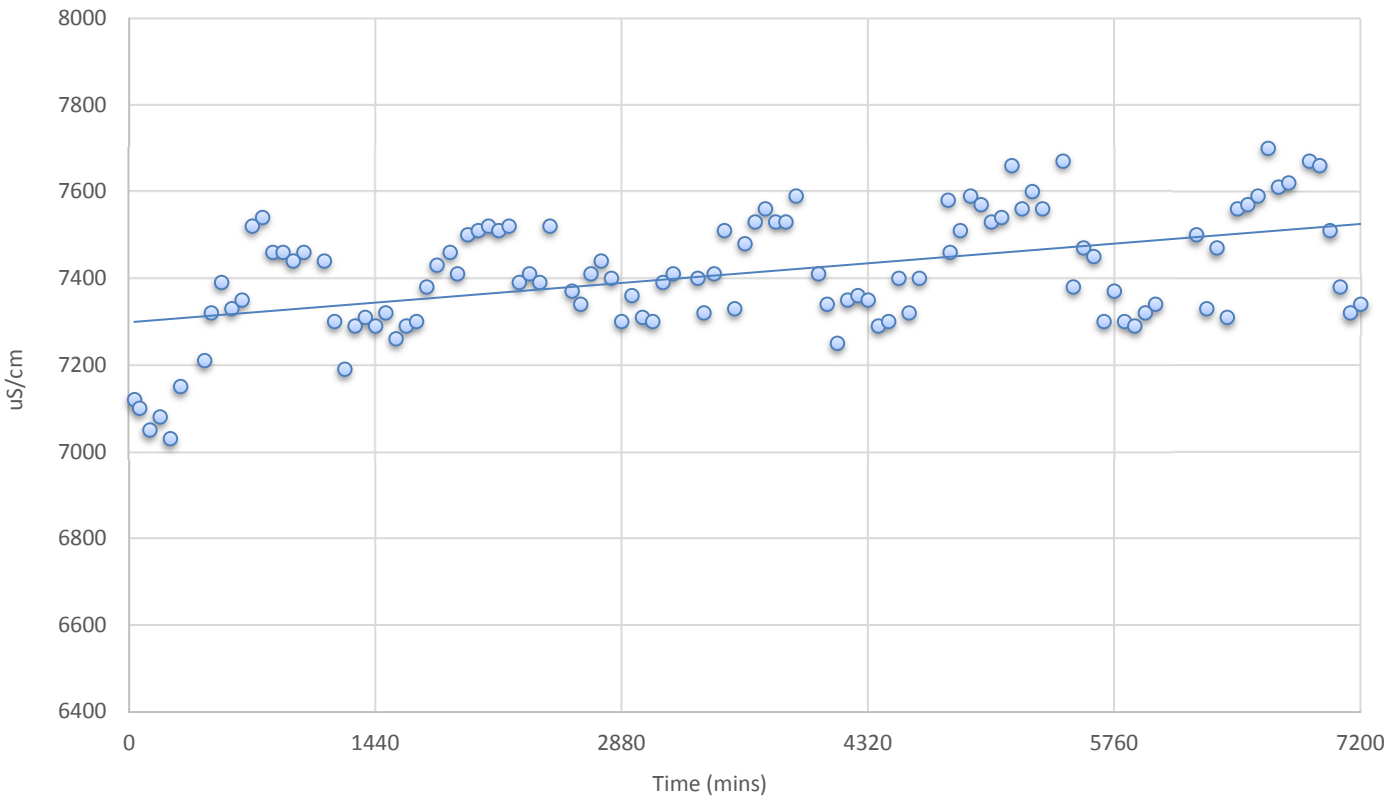
$Ew = (BQ/(BQ + CQ^P)) \times 100$

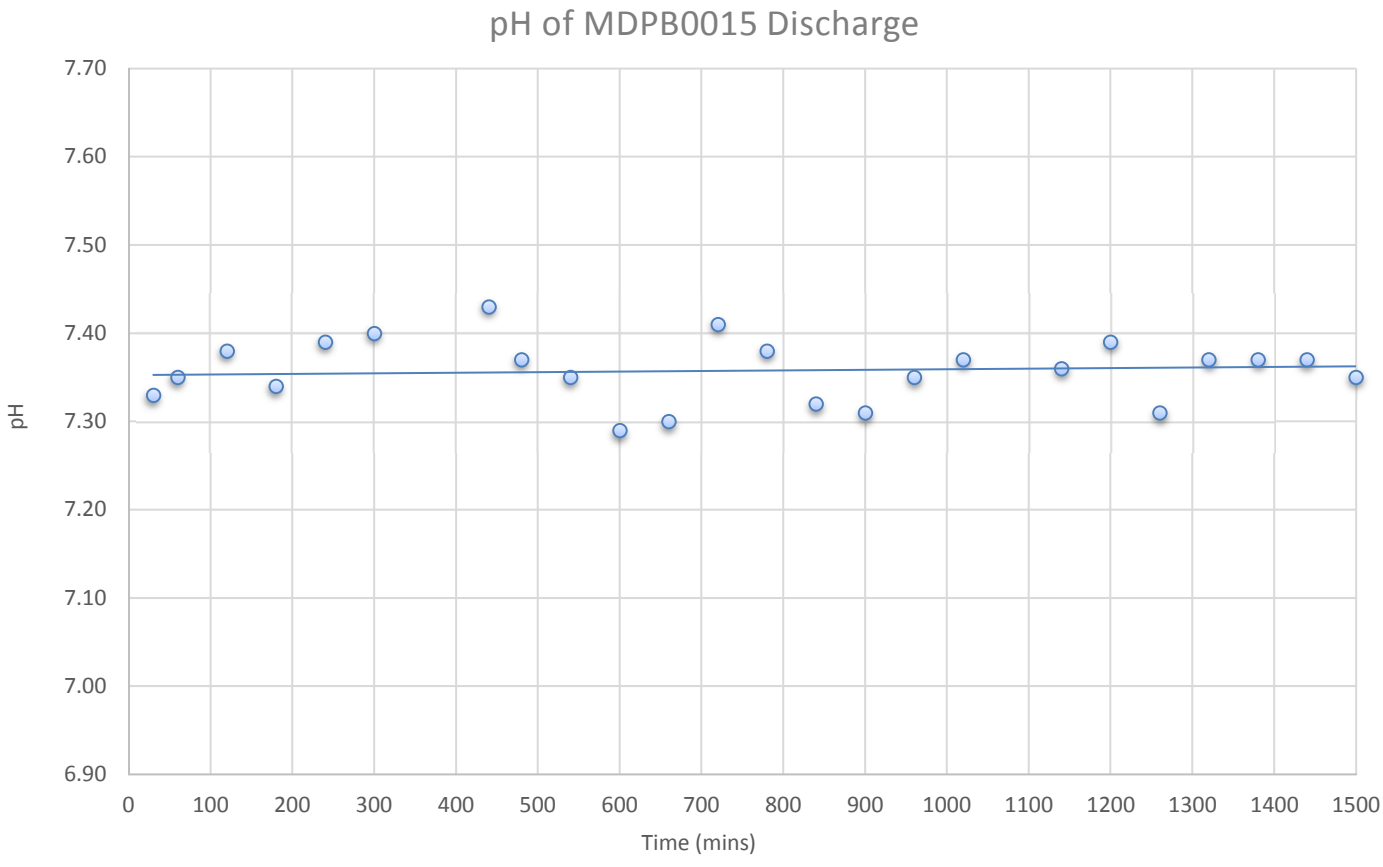
Ew or Well Efficiency represents the proportion of drawdown caused by laminar flow

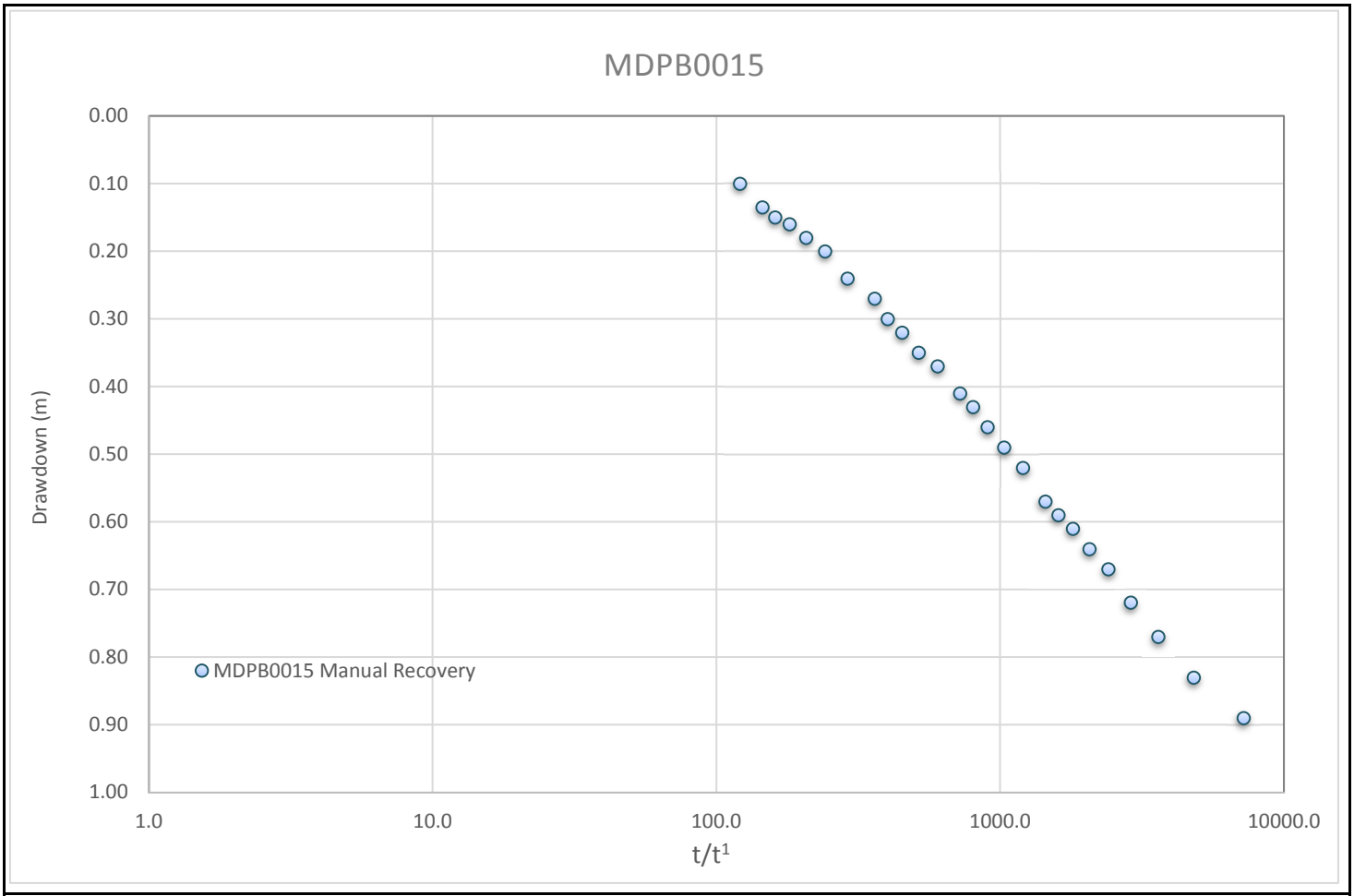
Comparison of Observed and Predicted Drawdowns						
Step (60 min steps)	Discharge (L/s)	Discharge (Q) (m3/d)	Observed Corrected Drawdown (s) (metres)	Predicted Drawdown (metres)	s/Q	Apparent Efficiency (Ew) %
1	10.0	864	1.67	1.70	0.0019	85.44
2	20.0	1728	3.98	3.89	0.0023	74.58
3	30.0	2592	6.59	6.57	0.0025	66.17
4	40.0	3456	9.67	9.75	0.0028	59.47

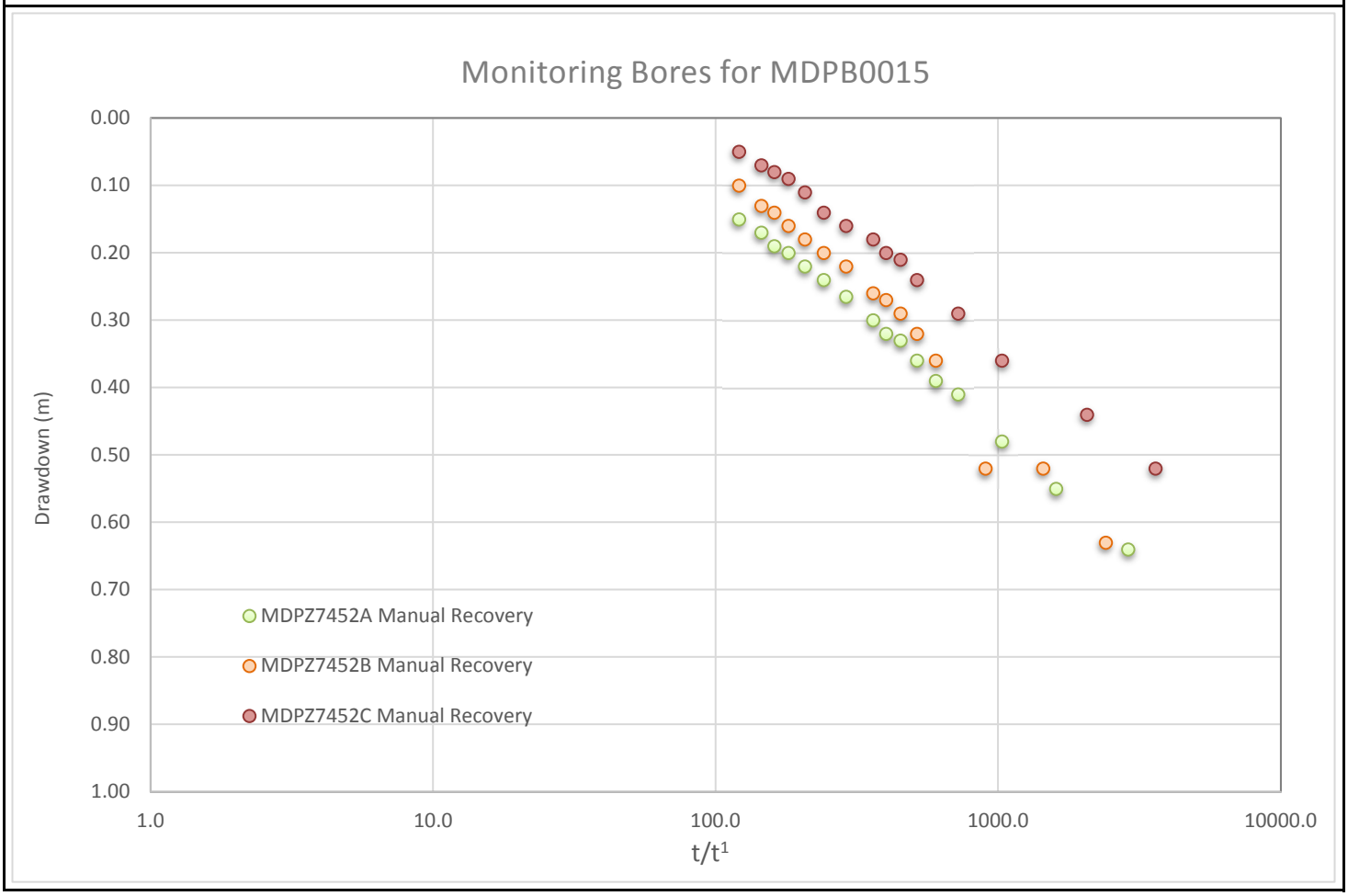

MDPB0015 Production Bore Drawdown
Pumping Rate = 40L/s
Pumping from: Undiff Tertiary & Pisolite
Drawdown (m)
8
8.5
9
9.5
10
10.5
1
10
100
1000
10000
Time (mins)
MDPB0015 Manual Drawdown
MDPB0015 Logger Drawdown

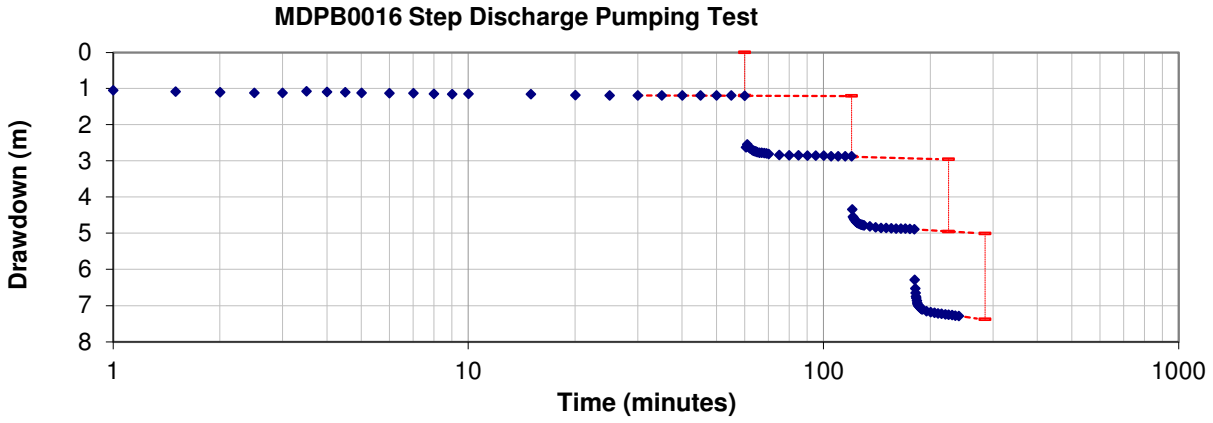

Monitoring Bores for CRT at MDP0015
Drawdown (m)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
1
10
100
1000
10000
Time (mins)
MDPZ7452C (Upper Calcrete)
MDPZ7452B (Undiff Tertiary)
MDPZ7452A (Basal Calcite & Dolomite)

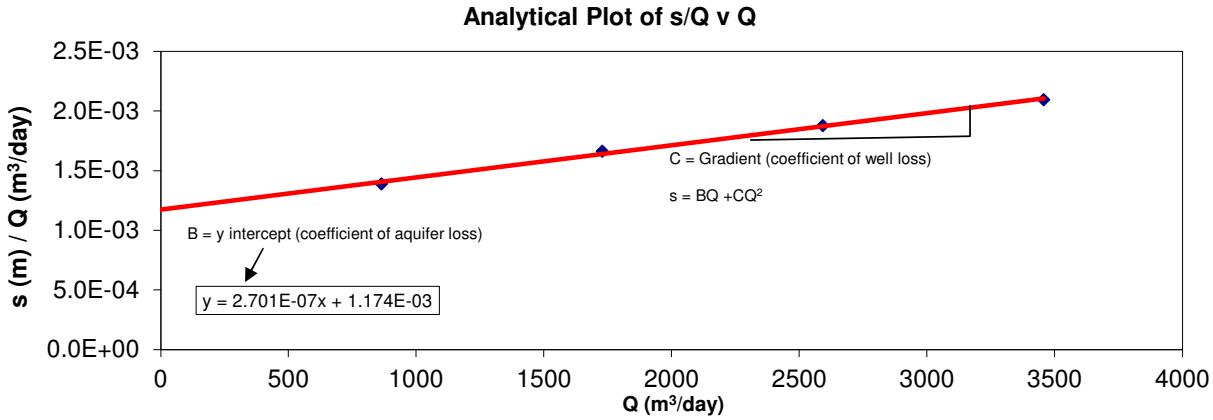

EC of MDPB0015 Discharge
8000
7800
7600
7400
7200
7000
6800
6600
6400
uS/cm
0
1440
2880
4320
5760
7200
Time (mins)


pH of MDPB0015 Discharge
7.70
7.60
7.50
7.40
7.30
7.20
7.10
7.00
6.90
pH
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
Time (mins)


MDPB0015
Drawdown (m)
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
1.0
10.0
100.0
1000.0
10000.0
t/t1
MDPB0015 Manual Recovery


Monitoring Bores for MDPB0015
Drawdown (m)
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
1.0
10.0
100.0
1000.0
10000.0
t/t1
MDPZ7452A Manual Recovery
MDPZ7452B Manual Recovery
MDPZ7452C Manual Recovery





$s_{w(n)} = BQ_n + CQ_n^P$ (Rorabaugh's equation)

Where: B = Intercept with y axis (coefficient of aquifer loss or laminar flow)
C = Gradient (coefficient of turbulent flow loss or apparent well loss)
s = Drawdown in the borehole
P = Value determined using Rorabaugh's method of superposition

Components of Jacob's (1947) equation BQ and CQ^2 are termed the aquifer loss and apparent well loss respectively. They give an indication of the proportion of total drawdown caused by laminar and turbulent flow.

Please note: 1. In thin or fissured aquifers large components of well loss are due to high flow velocities in the aquifer rather than inefficient bore design. Therefore, the term "apparent well loss" is better than well loss.
2. In aquifers where the flow horizons are vertically anisotropic, changes in bore performance often relate to changes in the rest water level with respect to the primary aquifer horizons.

$Ew = (BQ/(BQ + CQ^P)) \times 100$

Ew or Well Efficiency represents the proportion of drawdown caused by laminar flow

From plot of s/Q v Q (trend line equation):

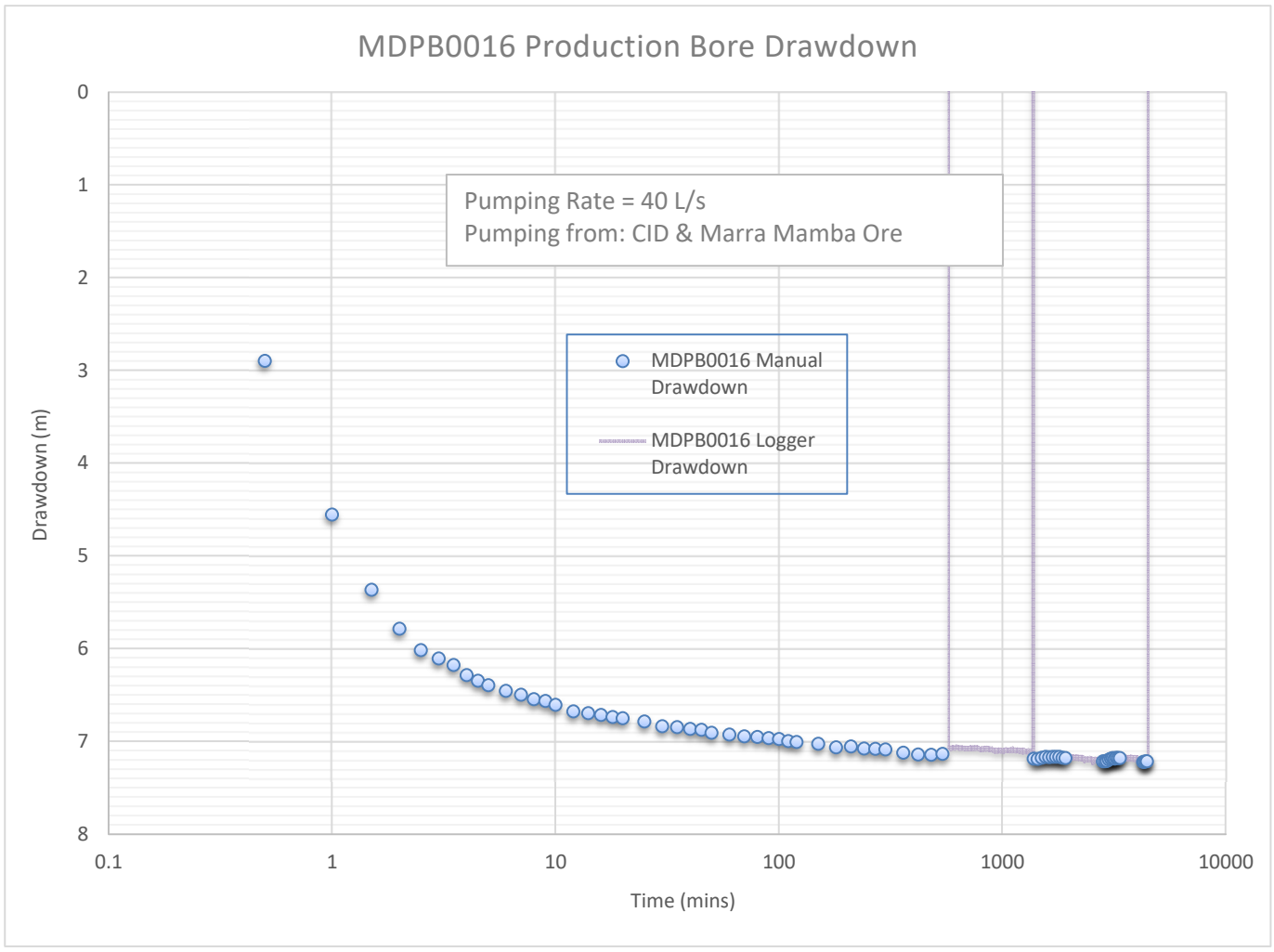
Intercept (B) 1.174E-03
Gradient (C) 2.701E-07

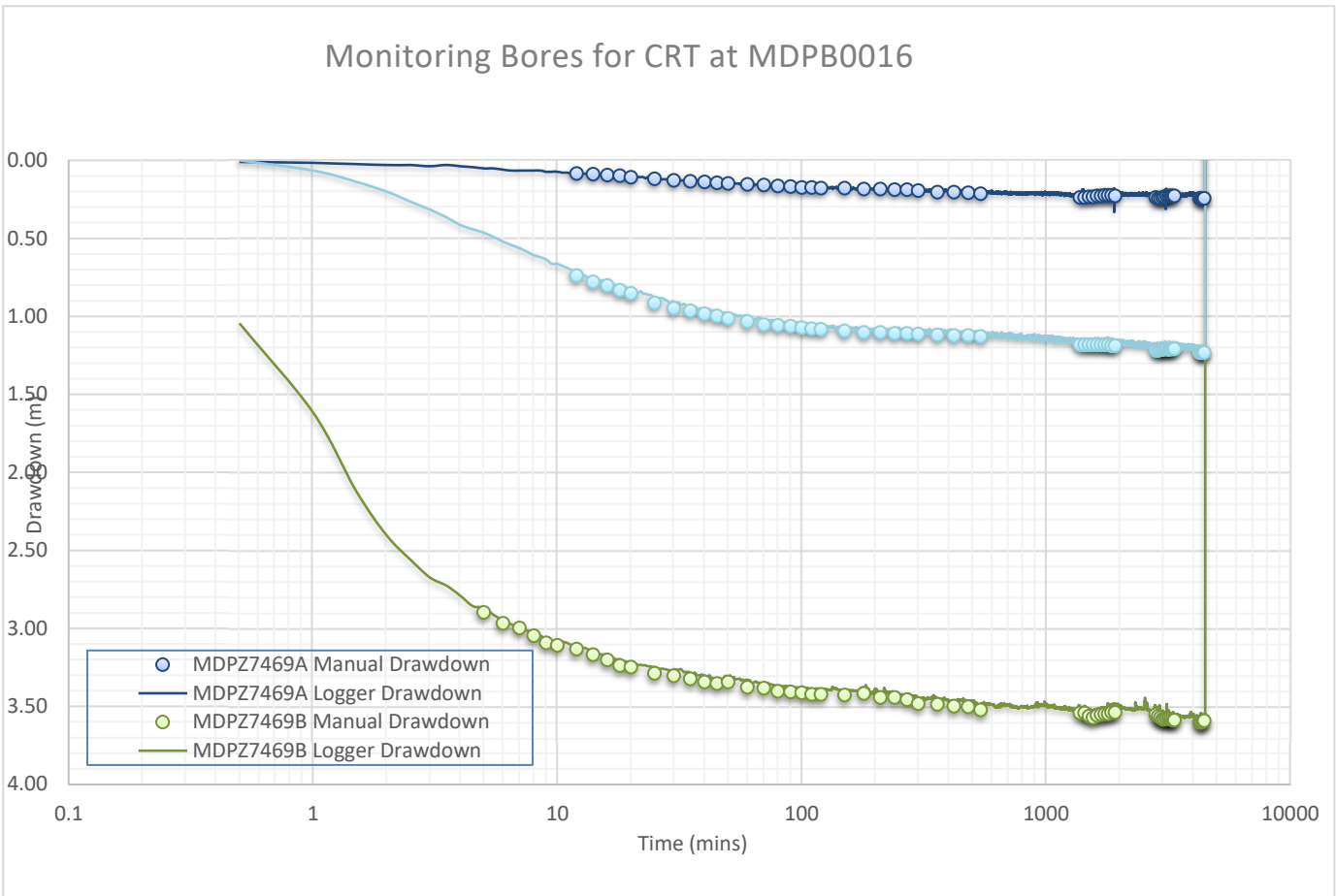
ANALYSIS TABLE

Calculation of well efficiency and comparison of observed and predicted drawdowns

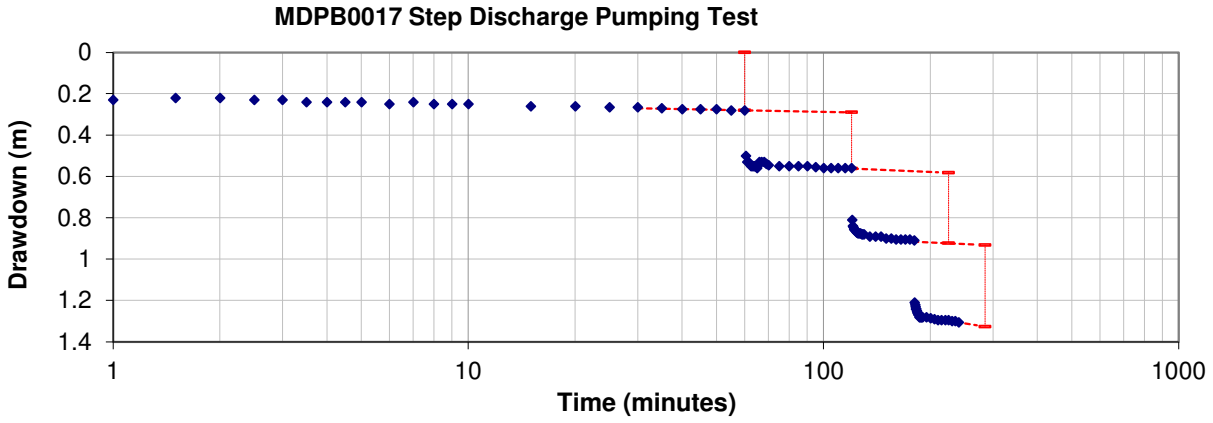
Step (duration)	Discharge (l/s)	Discharge (Q) (m^3/d)	Measured Incremental Drawdown (metres)	Corrected Drawdown (metres)	Predicted Drawdown (metres)	s/Q	Apparent Efficiency (Ew) %
1 (60 mins)	10.0	864	1.20	1.20	1.22	1.39E-03	83.4
2 (60 mins)	20.0	1728	1.68	2.88	2.83	1.66E-03	71.5
3 (60 mins)	30.0	2592	2.00	4.87	4.86	1.88E-03	62.6
4 (60 mins)	40.0	3456	2.37	7.24	7.28	2.09E-03	55.7

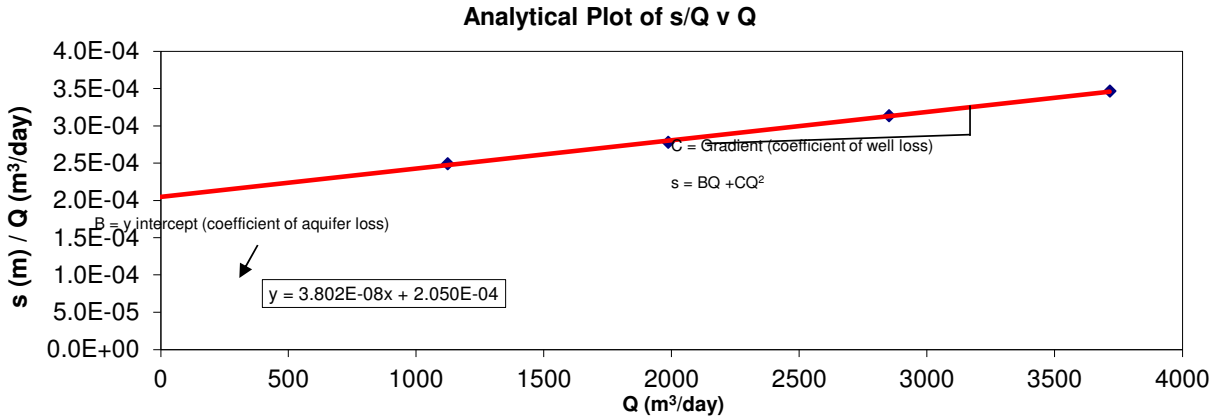
F:\171\2.TECH\PFS Test Pumping\MDPB0016\[MDPB0016_StepPlot60 v4_rev.xls]Plots & analysis





F:\171\2.TECH\PFS Test Pumping\MDPB0016\[MDPB0016 CRT Manual_Final.xlsm]Report Figure 1





$s_{w(n)} = BQ_n + CQ_n^P$ (Rorabaugh's equation)

Where: B = Intercept with y axis (coefficient of aquifer loss or laminar flow)
C = Gradient (coefficient of turbulent flow loss or apparent well loss)
s = Drawdown in the borehole
P = Value determined using Rorabaugh's method of superposition

Components of Jacob's (1947) equation BQ and CQ^2 are termed the aquifer loss and apparent well loss respectively. They give an indication of the proportion of total drawdown caused by laminar and turbulent flow.

Please note: 1. In thin or fissured aquifers large components of well loss are due to high flow velocities in the aquifer rather than inefficient bore design. Therefore, the term "apparent well loss" is better than well loss.
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$Ew = (BQ/(BQ + CQ^P)) \times 100$

Ew or Well Efficiency represents the proportion of drawdown caused by laminar flow

From plot of s/Q v Q (trend line equation):

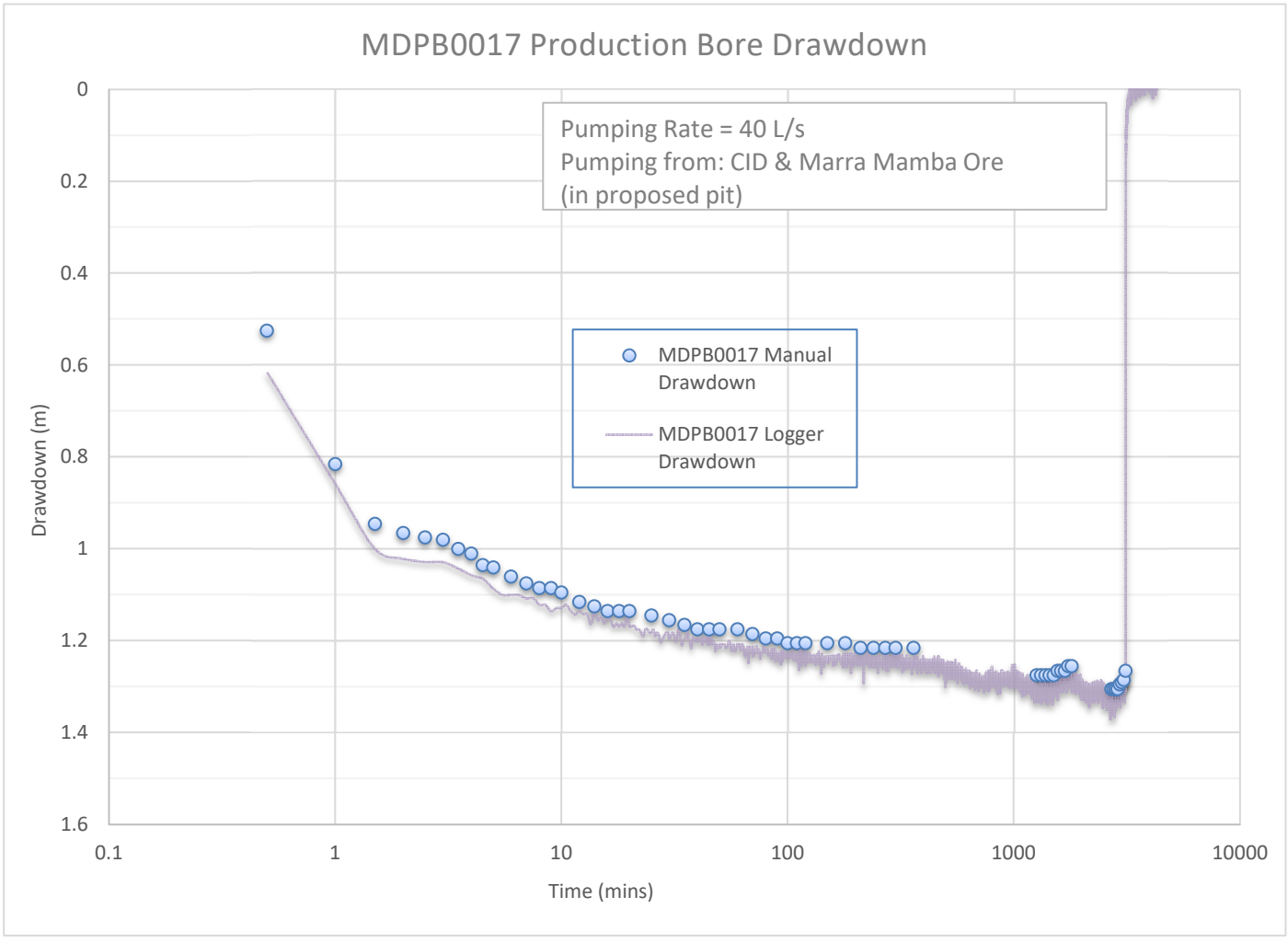
Intercept (B) 2.050E-04
Gradient (C) 3.802E-08

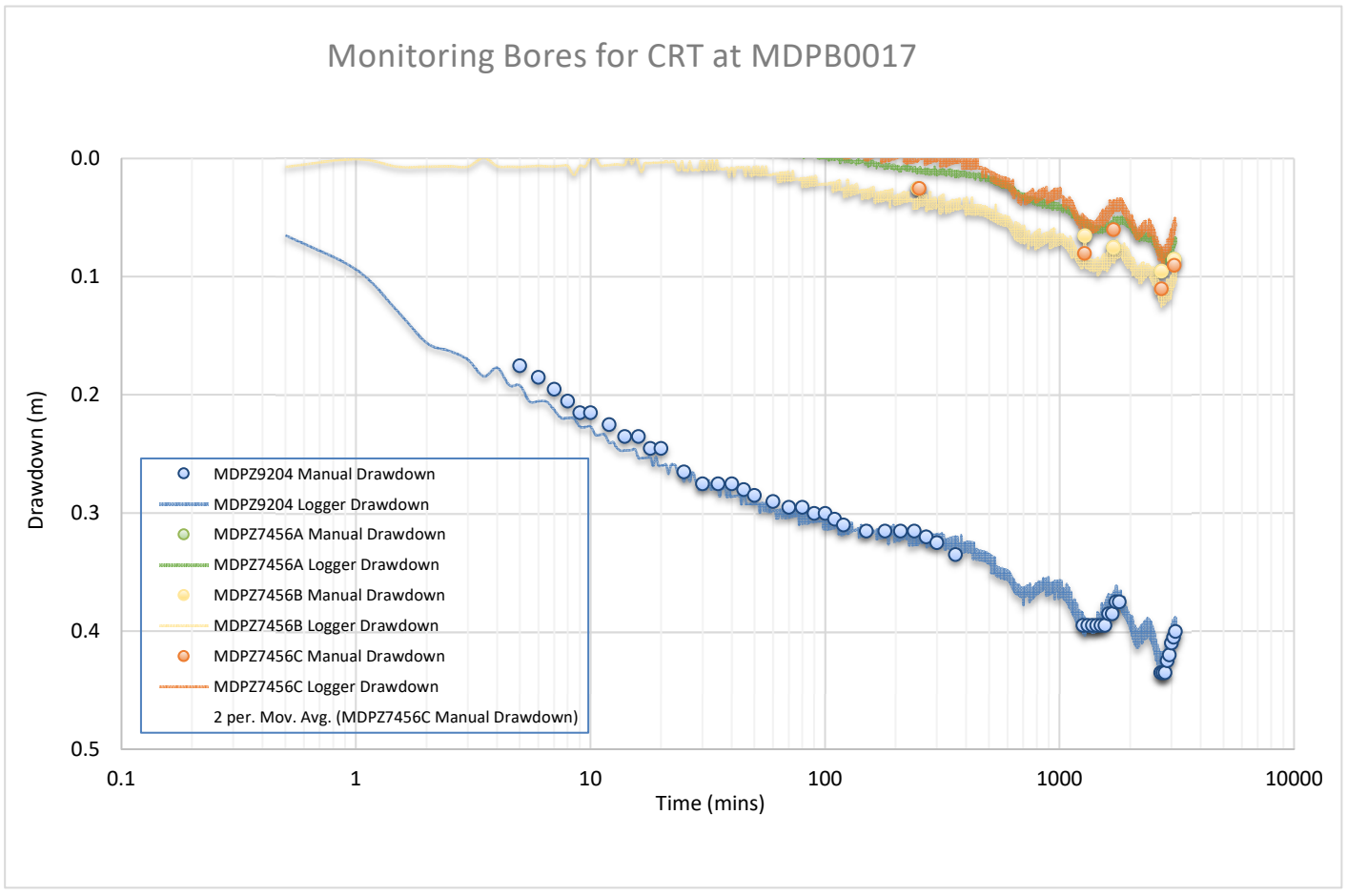
ANALYSIS TABLE

Calculation of well efficiency and comparison of observed and predicted drawdowns

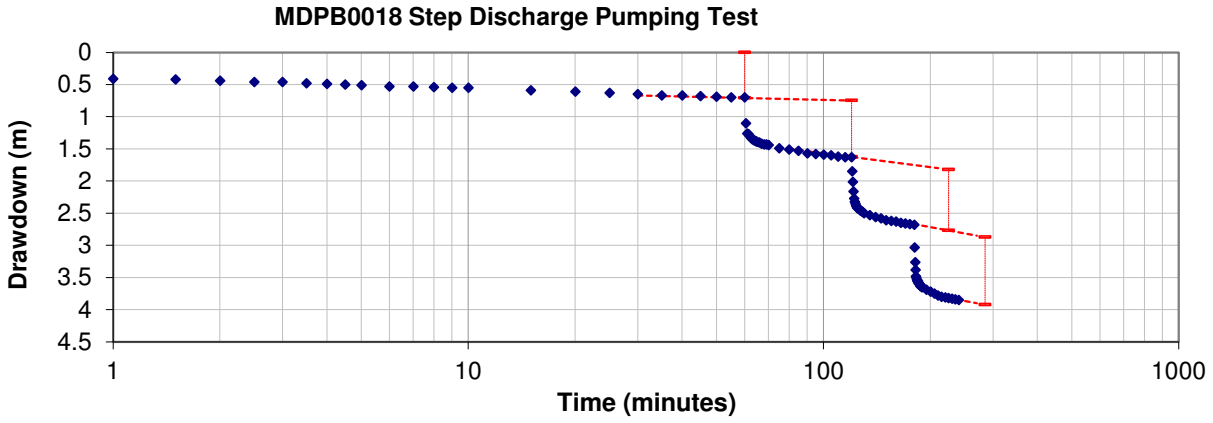
Step (duration)	Discharge (l/s)	Discharge (Q) (m^3/d)	Measured Incremental Drawdown (metres)	Corrected Drawdown (metres)	Predicted Drawdown (metres)	s/Q	Apparent Efficiency (Ew) %
1 (60 mins)	13.0	1123	0.28	0.28	0.28	2.49E-04	82.8
2 (60 mins)	23.0	1987	0.27	0.55	0.56	2.78E-04	73.1
3 (60 mins)	33.0	2851	0.34	0.89	0.89	3.14E-04	65.4
4 (60 mins)	43.0	3715	0.39	1.29	1.29	3.47E-04	59.2

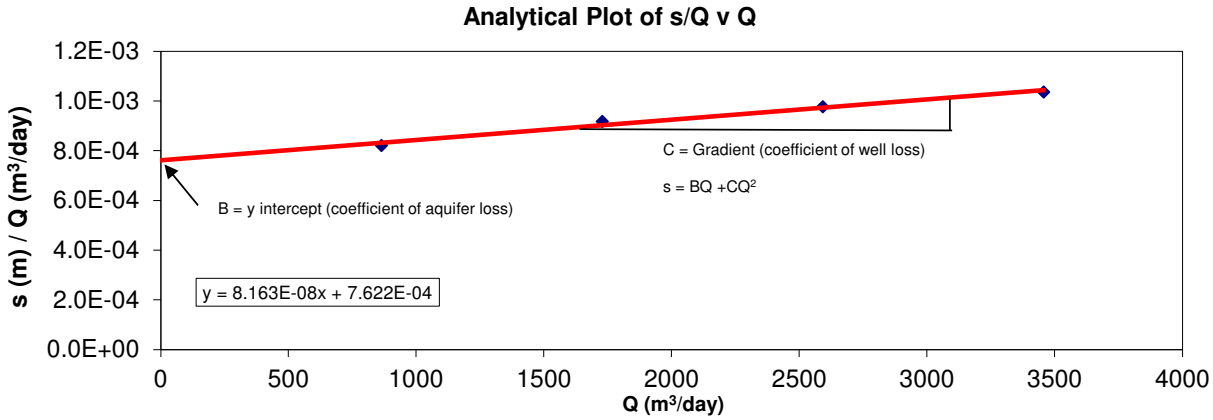
F:\171\2.TECH\PFS Test Pumping\MDPB0017\[MDPB0017_StepPlot60 v4_rev.xlsm]Plots & analysis





F:\171\2.TECH\PFS Test Pumping\MDPB0017\[MDPB0017 Aqtesolv Data.xlsx]Report Figure 1





$s_{w(n)} = BQ_n + CQ_n^P$ (Rorabaugh's equation)

Where: B = Intercept with y axis (coefficient of aquifer loss or laminar flow)
C = Gradient (coefficient of turbulent flow loss or apparent well loss)
s = Drawdown in the borehole
P = Value determined using Rorabaugh's method of superposition

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$Ew = (BQ/(BQ + CQ^P)) \times 100$

Ew or Well Efficiency represents the proportion of drawdown caused by laminar flow

From plot of s/Q v Q (trend line equation):

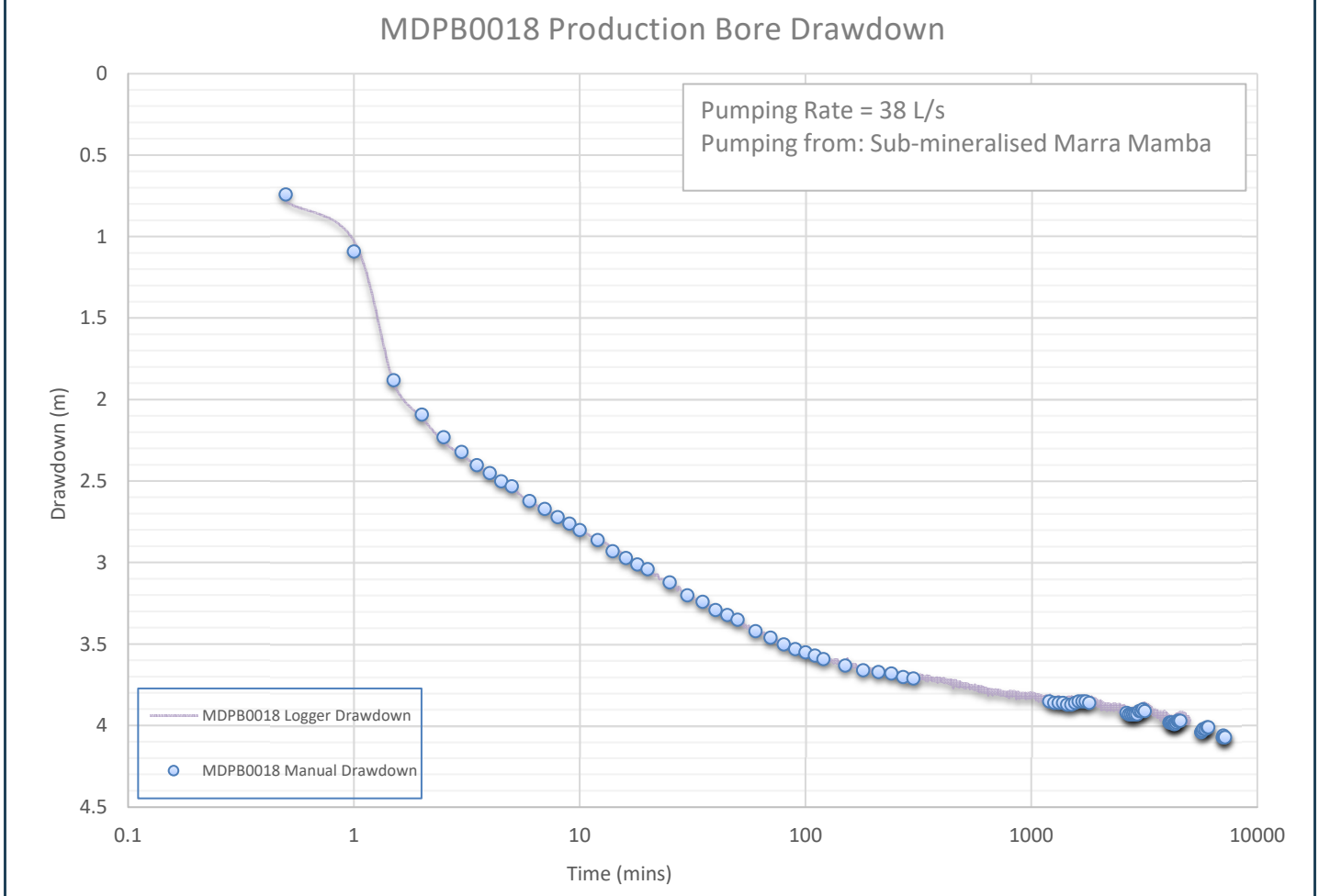
Intercept (B) 7.622E-04
Gradient (C) 8.163E-08

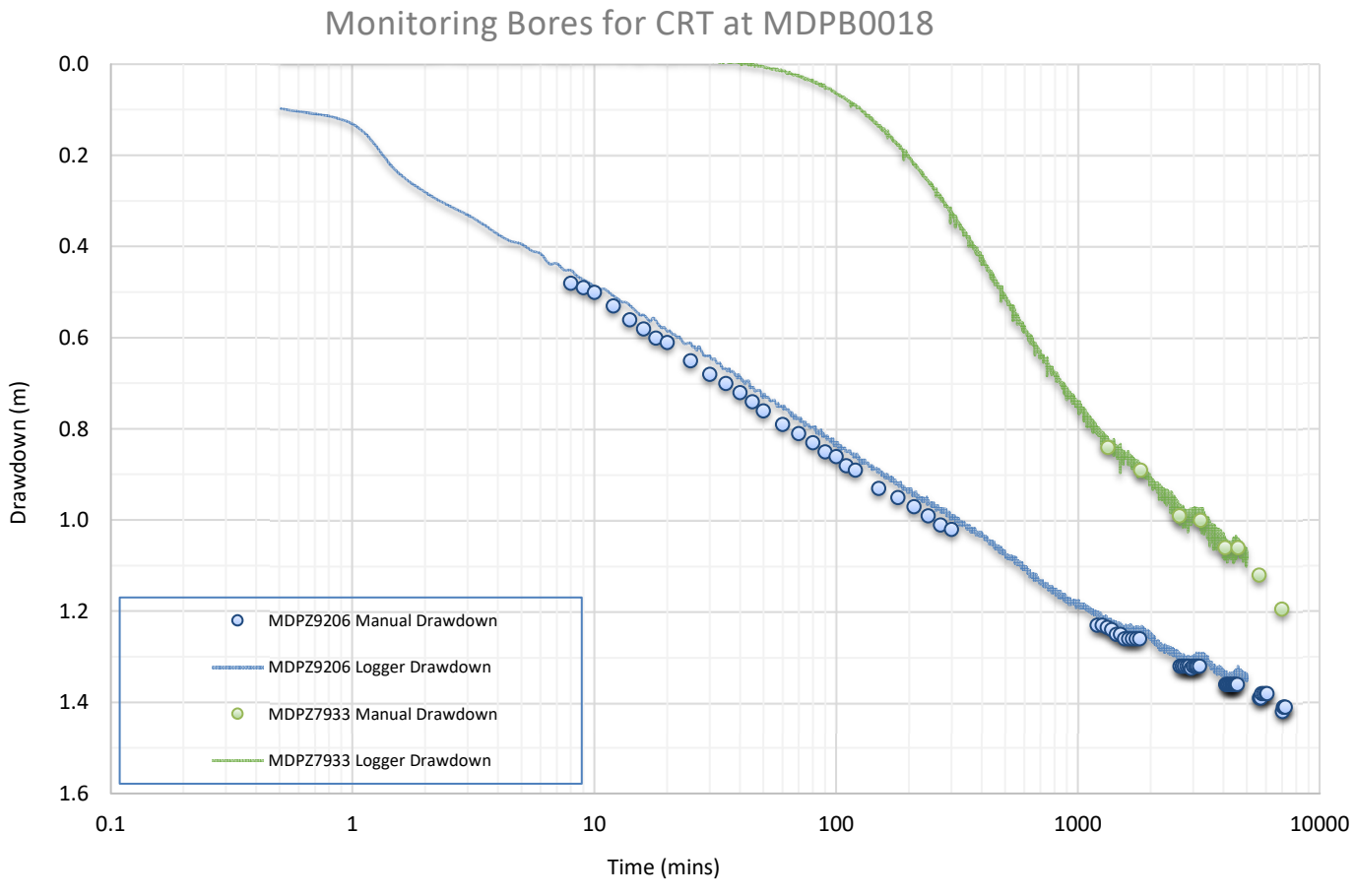
ANALYSIS TABLE

Calculation of well efficiency and comparison of observed and predicted drawdowns

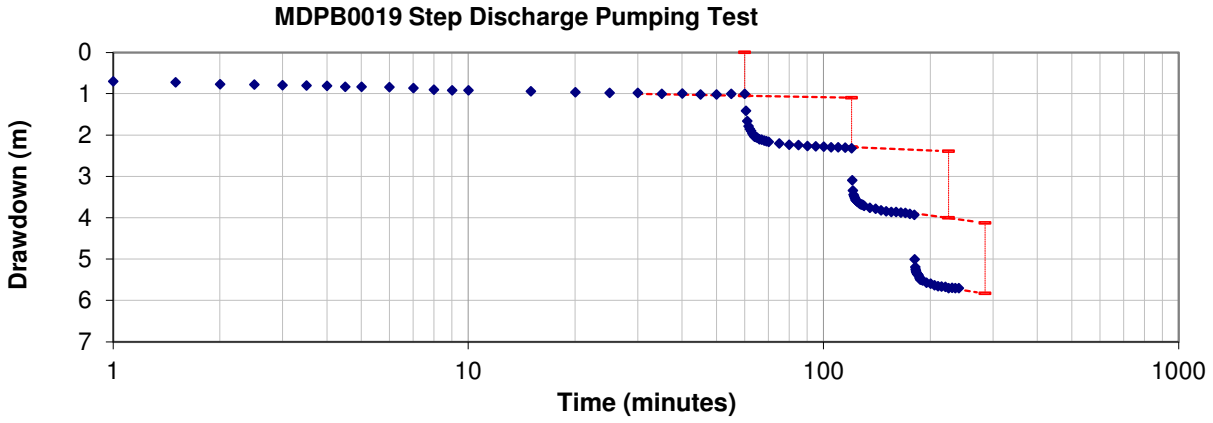
Step (duration)	Discharge (l/s)	Discharge (Q) (m^3/d)	Measured Incremental Drawdown (metres)	Corrected Drawdown (metres)	Predicted Drawdown (metres)	s/Q	Apparent Efficiency (Ew) %
1 (60 mins)	10.0	864	0.71	0.71	0.72	8.22E-04	91.5
2 (60 mins)	20.0	1728	0.88	1.59	1.56	9.18E-04	84.4
3 (60 mins)	30.0	2592	0.95	2.53	2.52	9.78E-04	78.3
4 (60 mins)	40.0	3456	1.05	3.58	3.61	1.04E-03	73.0

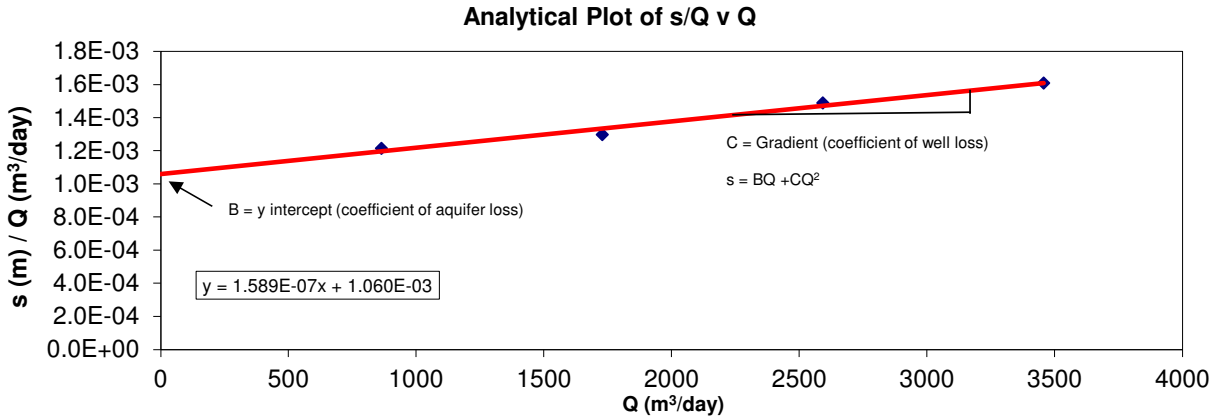
F:\171\2.TECH\PFS Test Pumping\MDPB0018\[MDPB0018_StepPlot60 v4_rev.xls]Plots & analysis





F:\171\2.TECH\PFS Test Pumping\MDPB0018\[MDPB0018 Aqtesolv Data.xlsx]Report Figure 1





$s_{w(n)} = BQ_n + CQ_n^P$ (Rorabaugh's equation)

Where: B = Intercept with y axis (coefficient of aquifer loss or laminar flow)
C = Gradient (coefficient of turbulent flow loss or apparent well loss)
s = Drawdown in the borehole
P = Value determined using Rorabaugh's method of superposition

Components of Jacob's (1947) equation BQ and CQ^2 are termed the aquifer loss and apparent well loss respectively. They give an indication of the proportion of total drawdown caused by laminar and turbulent flow.

Please note: 1. In thin or fissured aquifers large components of well loss are due to high flow velocities in the aquifer rather than inefficient bore design. Therefore, the term "apparent well loss" is better than well loss.
2. In aquifers where the flow horizons are vertically anisotropic, changes in bore performance often relate to changes in the rest water level with respect to the primary aquifer horizons.

$Ew = (BQ/(BQ + CQ^P)) \times 100$

Ew or Well Efficiency represents the proportion of drawdown caused by laminar flow

From plot of s/Q v Q (trend line equation):

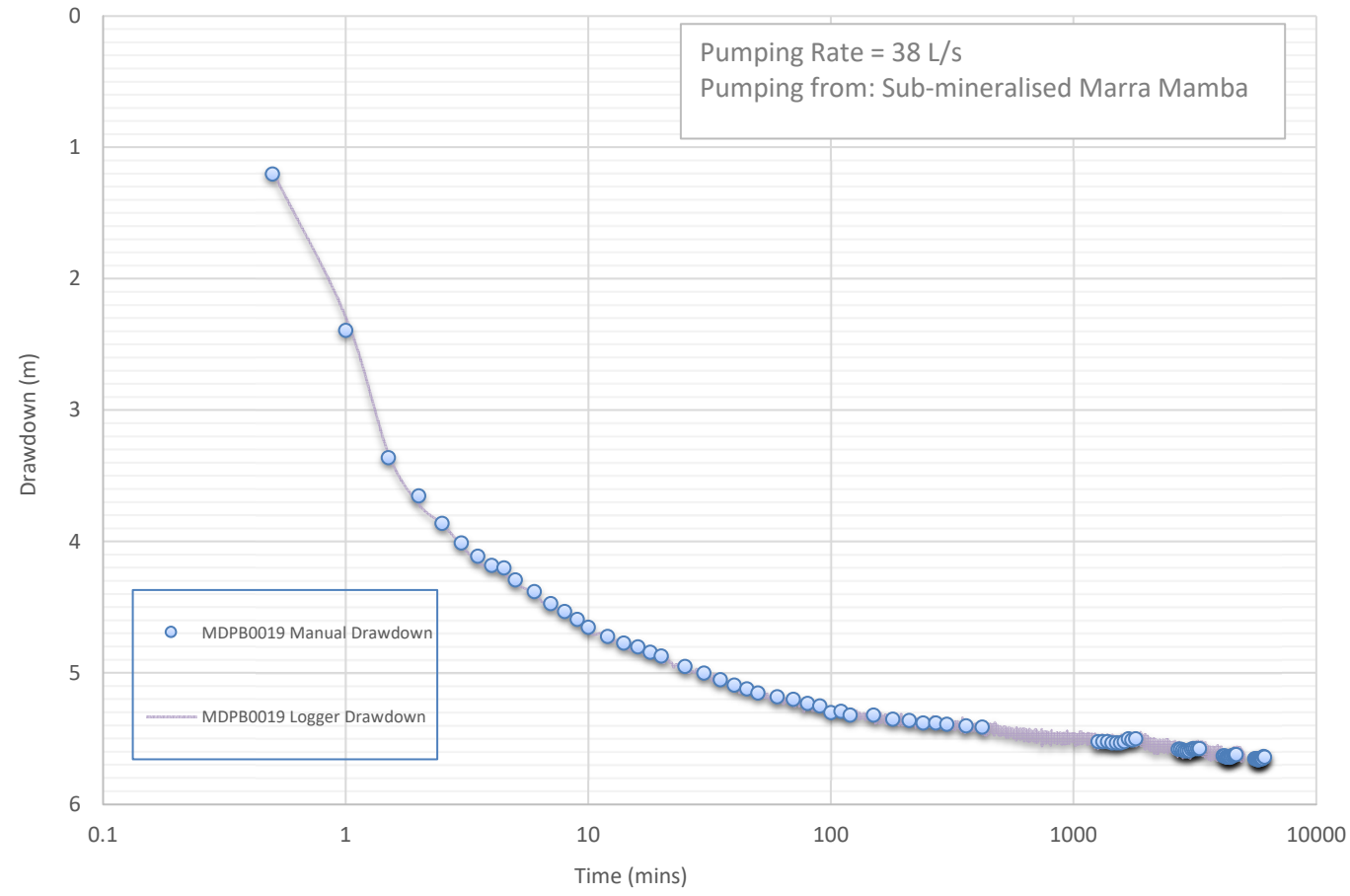
Intercept (B) 1.060E-03
Gradient (C) 1.589E-07

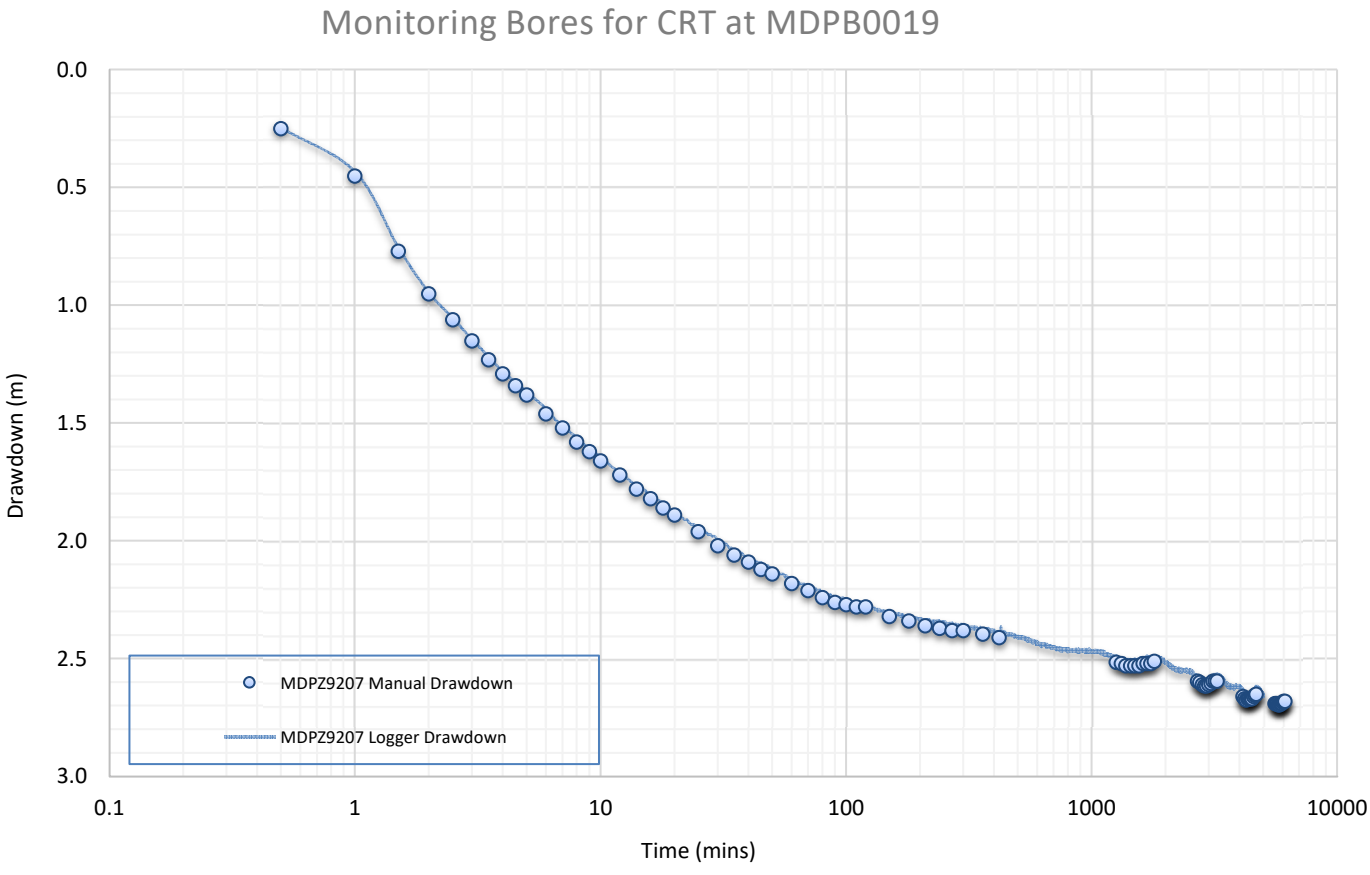
ANALYSIS TABLE

Calculation of well efficiency and comparison of observed and predicted drawdowns

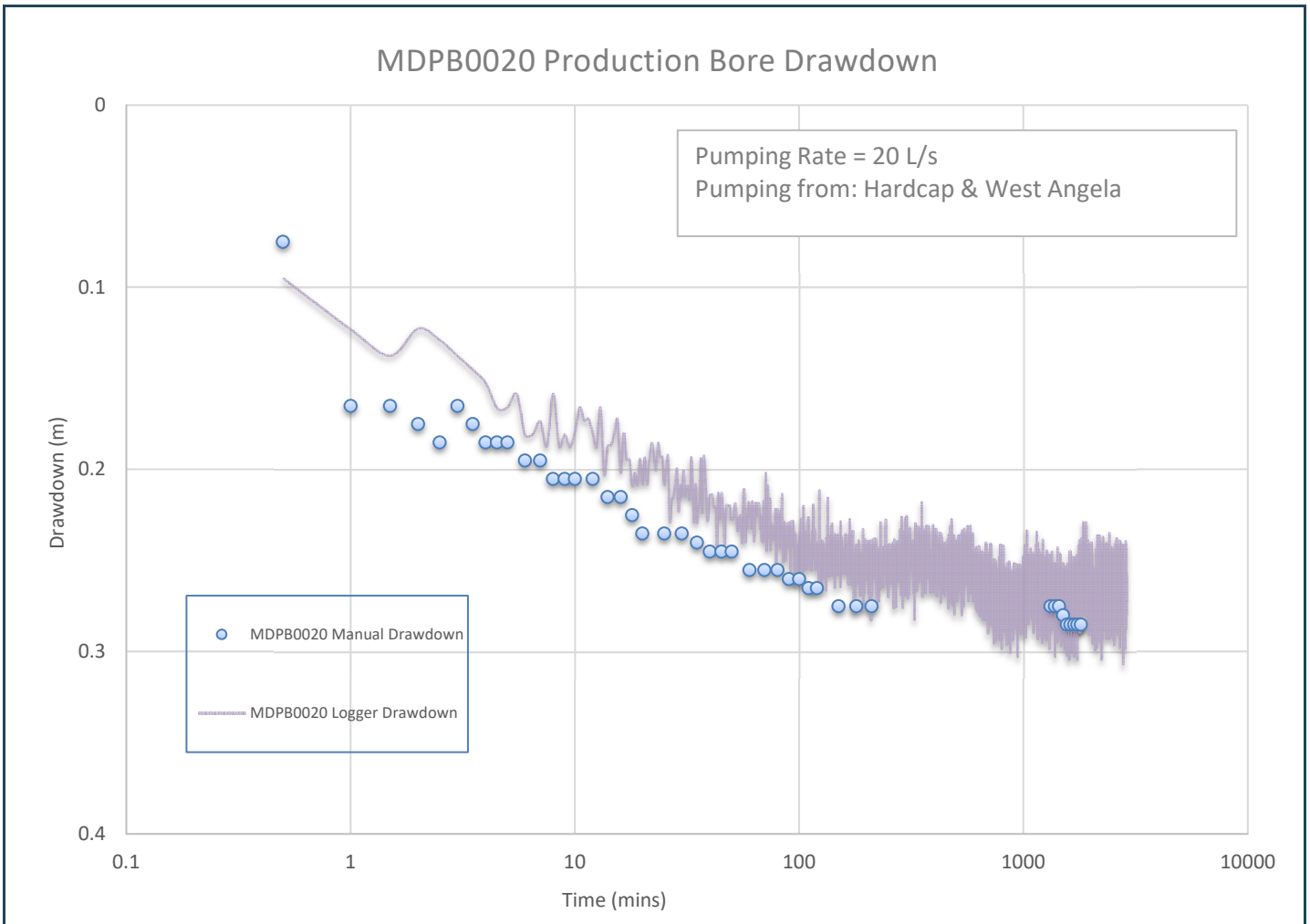
Step (duration)	Discharge (l/s)	Discharge (Q) (m^3/d)	Measured Incremental Drawdown (metres)	Corrected Drawdown (metres)	Predicted Drawdown (metres)	s/Q	Apparent Efficiency (Ew) %
1 (60 mins)	10.0	864	1.05	1.05	1.03	1.22E-03	88.5
2 (60 mins)	20.0	1728	1.19	2.24	2.31	1.30E-03	79.4
3 (60 mins)	30.0	2592	1.62	3.86	3.81	1.49E-03	72.0
4 (60 mins)	40.0	3456	1.70	5.56	5.56	1.61E-03	65.9

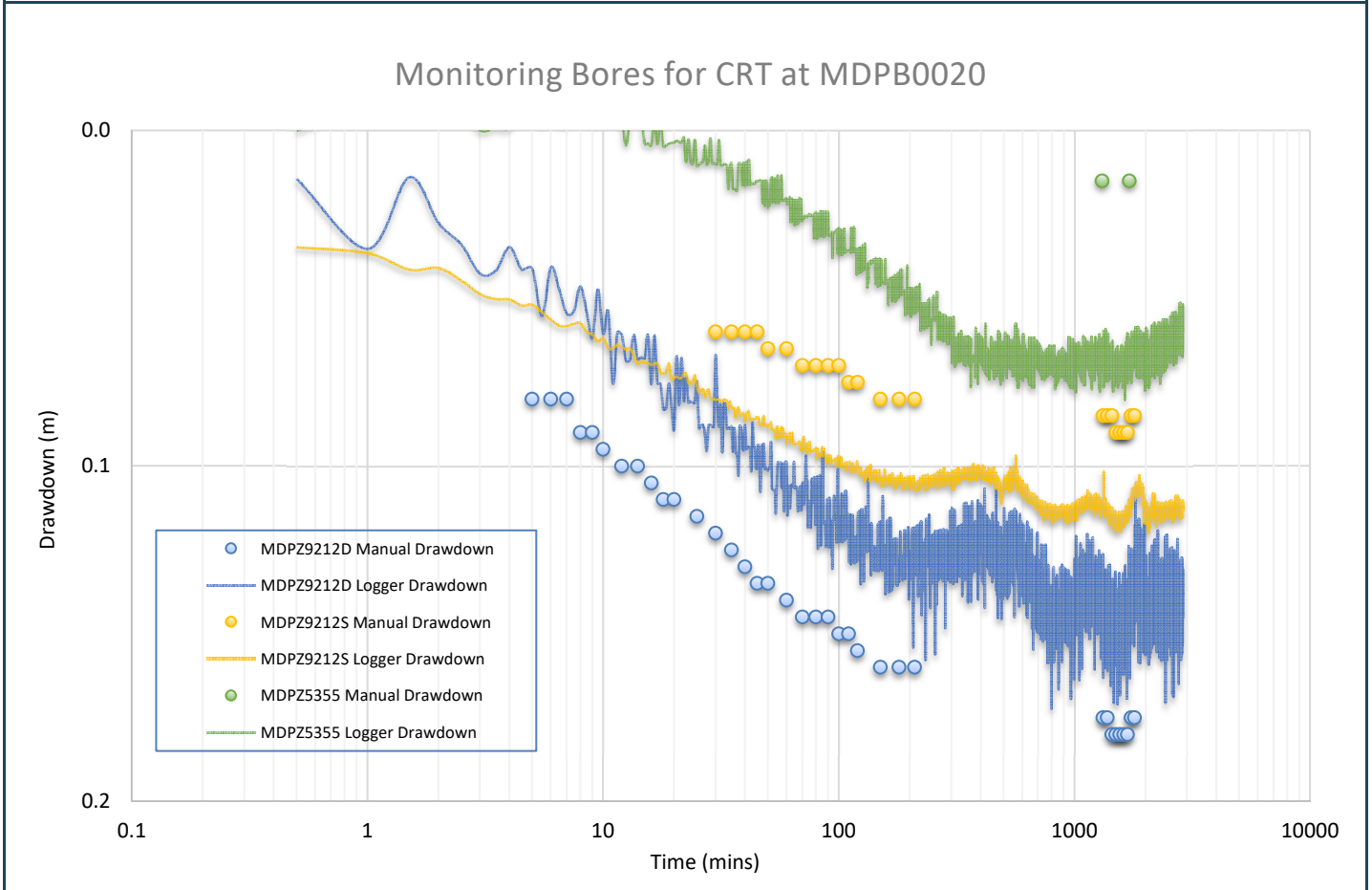
F:\171\2.TECH\PFS Test Pumping\MDPB0019\[MDPB0019_StepPlot60 v4_rev.xlsm]Plots & analysis





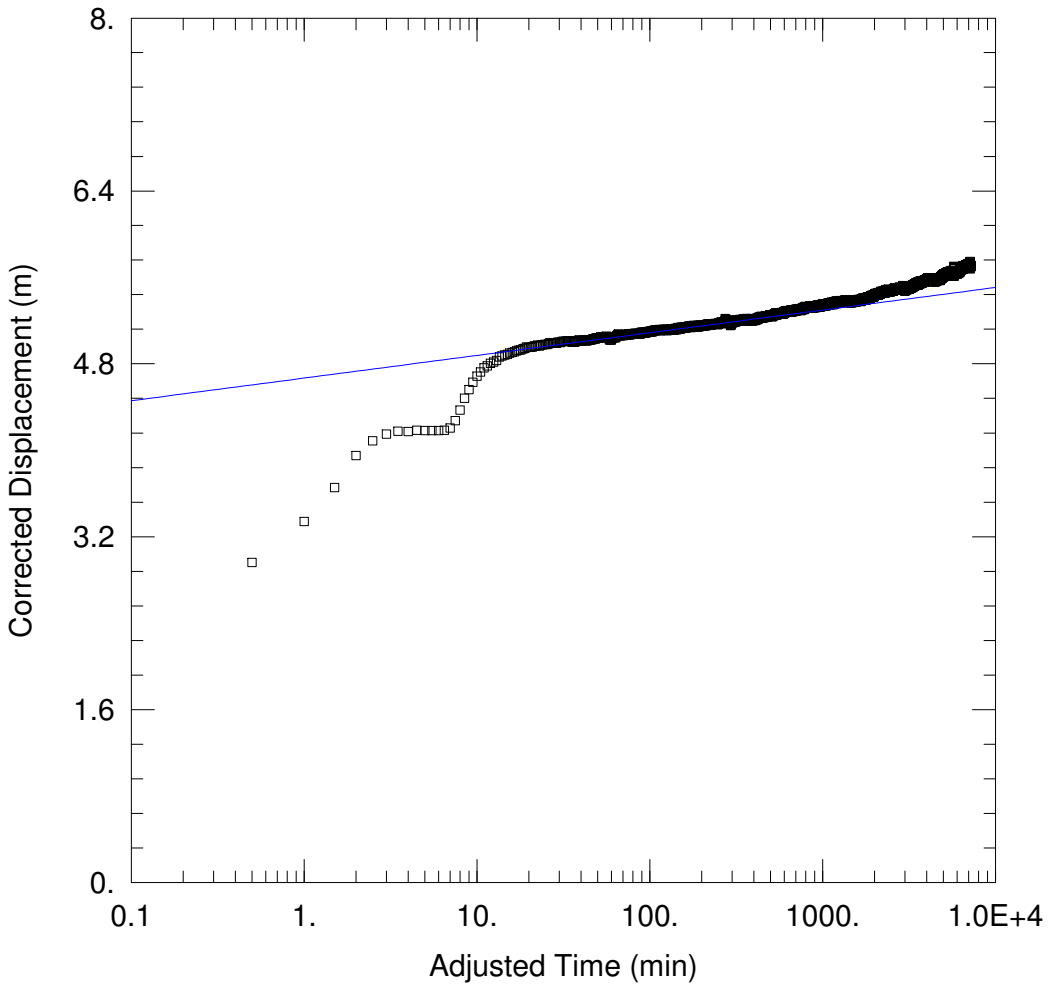
F:\171\2.TECH\PFS Test Pumping\MDPB0019\[MDPB0019 Aqtesolv Data.xlsx]Report Figure 1





F:\171\2.TECH\PFS Test Pumping\MDPB0020\[MDPB0020 Aqtesolv Data_.xlsx]Report Figure 1

APPENDIX F
HYDRAULIC ANALYSES PLOTS 2018–2023



WELL TEST ANALYSIS

Data Set: F:\171\2.TECH\Test Pumping\MDPB0011\MDPB0011.aqt
Date: 10/10/19 Time: 13:15:46

PROJECT INFORMATION

Company: AQ2
Client: HPPL
Project: 171
Location: Mulga Downs
Test Well: MDPB0011

AQUIFER DATA

Saturated Thickness: 16. m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0011	652204	7552525

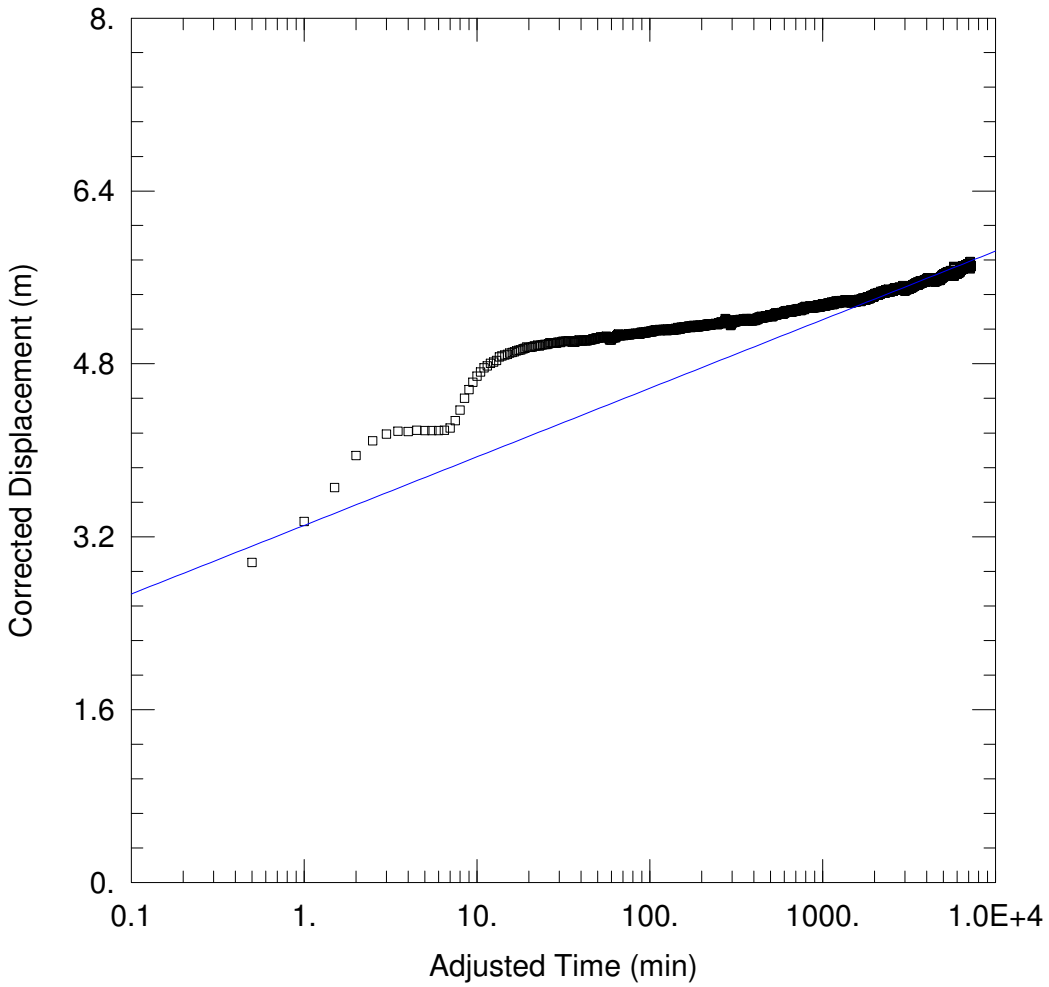
Observation Wells

Well Name	X (m)	Y (m)
▫ MDPB0011	652204	7552525

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 528.6 m^2/day S = 1.115E-21



WELL TEST ANALYSIS

Data Set: F:\171\2.TECH\Test Pumping\MDPB0011\MDPB0011.aqt
Date: 10/10/19 Time: 13:15:19

PROJECT INFORMATION

Company: AQ2
Client: HPPL
Project: 171
Location: Mulga Downs
Test Well: MDPB0011

AQUIFER DATA

Saturated Thickness: 16. m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0011	652204	7552525

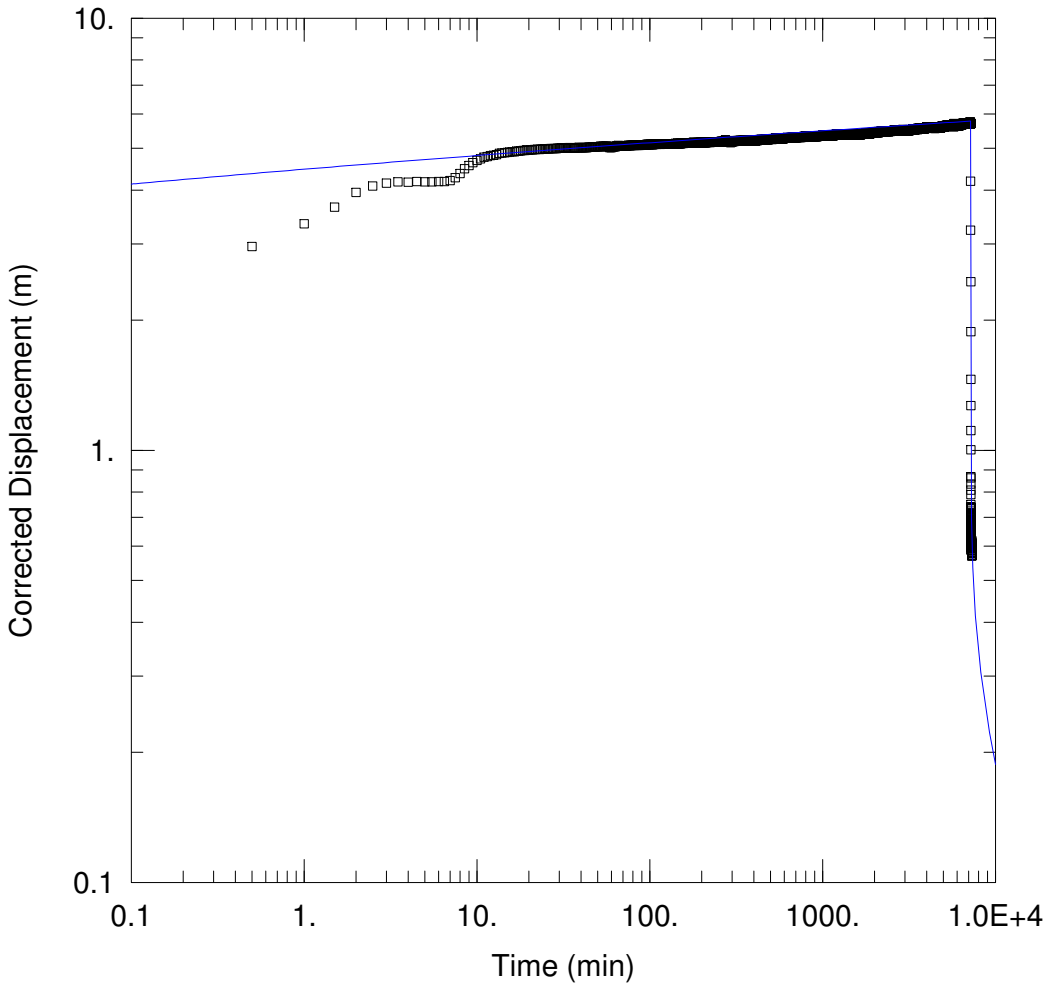
Observation Wells

Well Name	X (m)	Y (m)
MDPB0011	652204	7552525

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 174.6 m^2/day S = 4.246E-5



WELL TEST ANALYSIS

Data Set: F:\171\2.TECH\Test Pumping\MDPB0011\MDPB0011.aqt
Date: 10/10/19 Time: 13:14:21

PROJECT INFORMATION

Company: AQ2
Client: HPPL
Project: 171
Location: Mulga Downs
Test Well: MDPB0011

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0011	652204	7552525

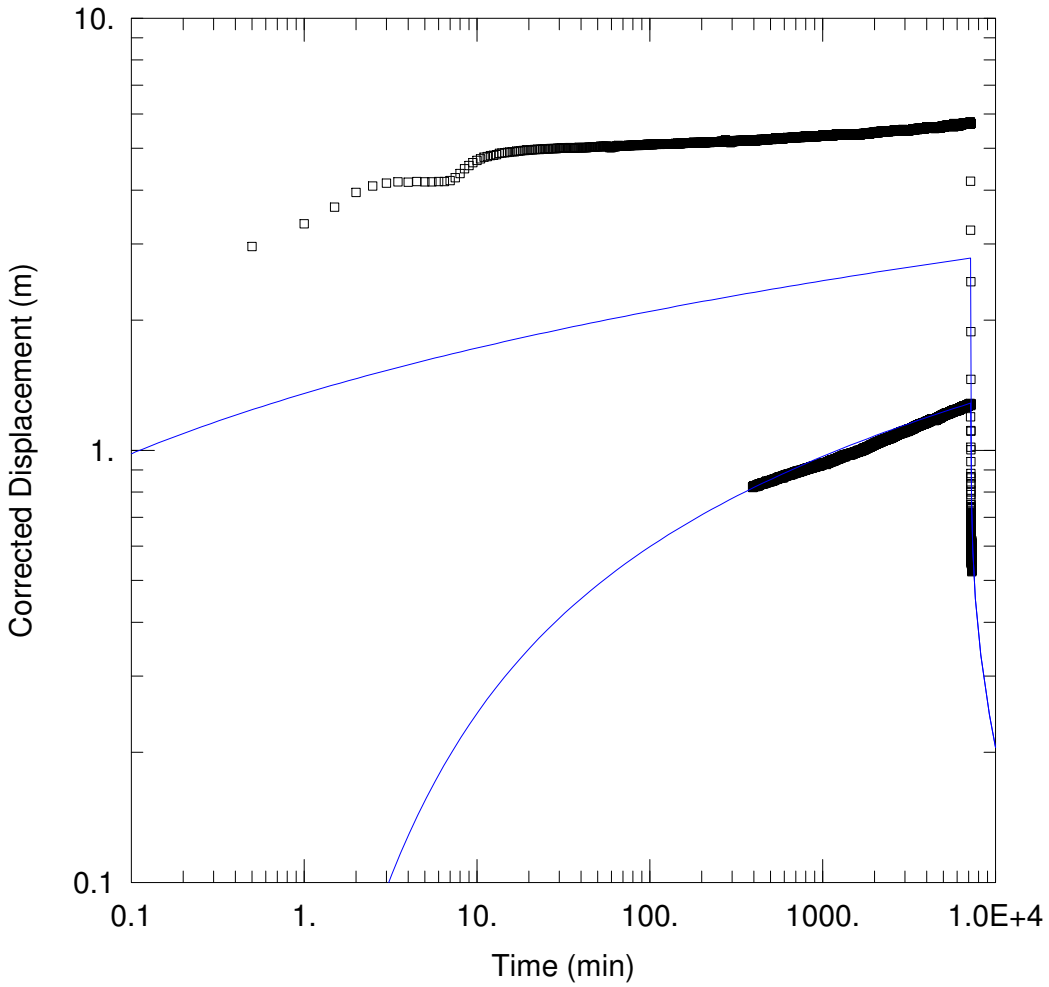
Observation Wells

Well Name	X (m)	Y (m)
▫ MDPB0011	652204	7552525

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 327. m^2/day
Kz/Kr = 0.1
S = 8.226E-13
b = 16. m



WELL TEST ANALYSIS

Data Set: F:\171\2.TECH\Test Pumping\MDPB0011\MDPB0011.aqt
Date: 02/14/20 Time: 10:11:28

PROJECT INFORMATION

Company: AQ2
Client: HPPL
Project: 171
Location: Mulga Downs
Test Well: MDPB0011

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0011	652201.706	7552524.951

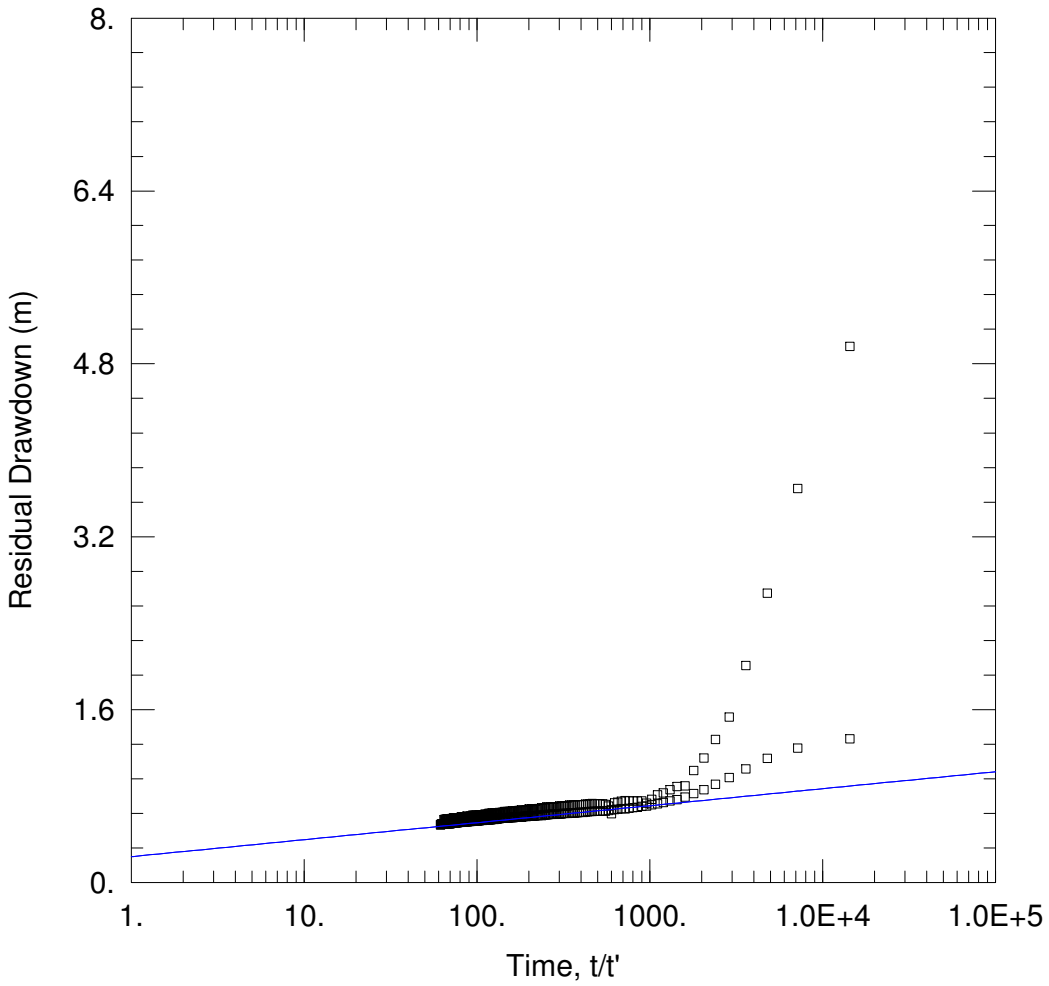
Observation Wells

Well Name	X (m)	Y (m)
MDPZ7450C	652197.73	7552504.429
MDPB0011	652201.706	7552524.951

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 298.3 m^2/day
S = 0.002654
Kz/Kr = 0.05859
b = 16. m



WELL TEST ANALYSIS

Data Set: F:\171\2.TECH\Test Pumping\MDPB0011\MDPB0011.aqt
Date: 02/14/20 Time: 10:13:02

PROJECT INFORMATION

Company: AQ2
Client: HPPL
Project: 171
Location: Mulga Downs
Test Well: MDPB0011

AQUIFER DATA

Saturated Thickness: 16. m Anisotropy Ratio (Kz/Kr): 0.05859

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0011	652201.706	7552524.951

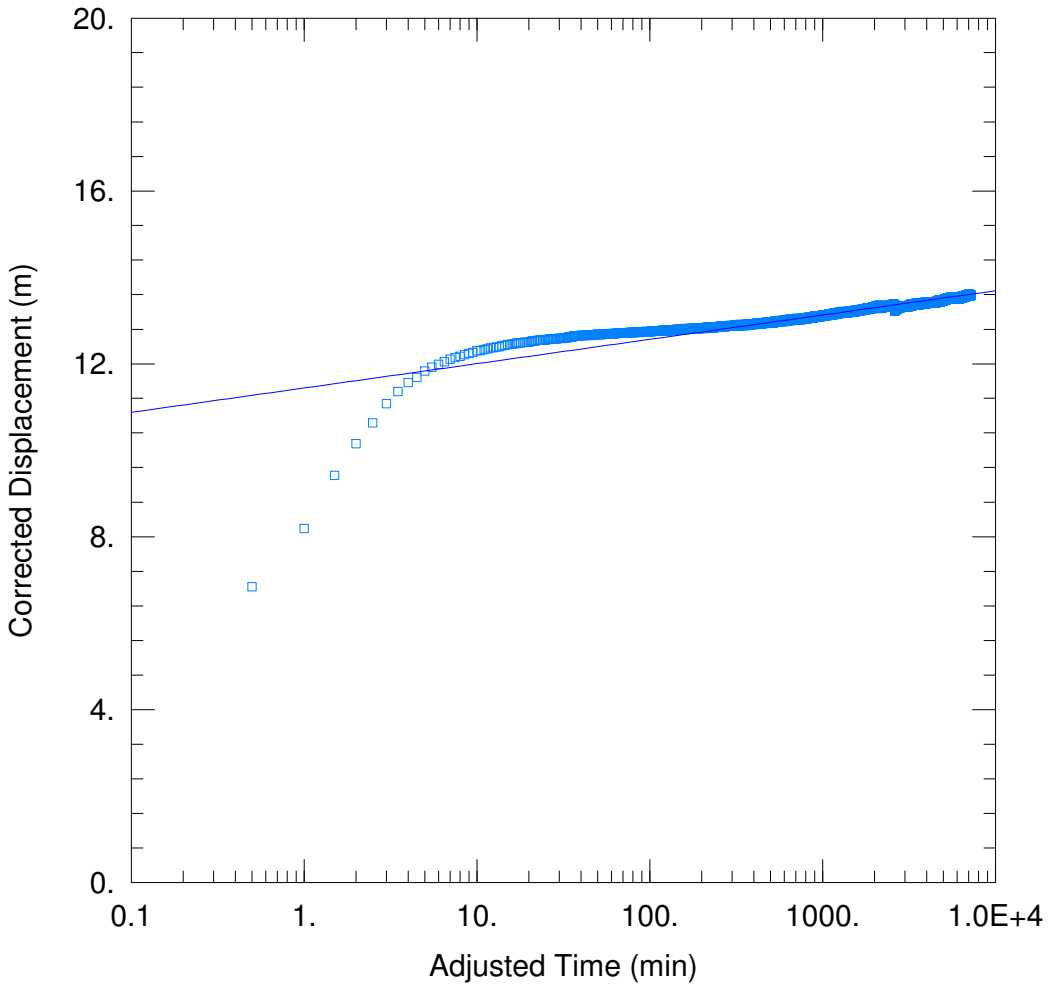
Observation Wells

Well Name	X (m)	Y (m)
MDPZ7450C	652197.73	7552504.429
MDPB0011	652201.706	7552524.951

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 704.8 m^2/day S/S' = 0.03067



WELL TEST ANALYSIS

Data Set: F:\171\2.TECH\Test Pumping\MDPB0012\MDPB0012.aqt
Date: 10/10/19 Time: 13:17:13

PROJECT INFORMATION

Company: AQ2
Client: HPPL
Project: 171
Location: Mulga Downs
Test Well: MDPB0012

AQUIFER DATA

Saturated Thickness: 38. m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0012	655677	7551804

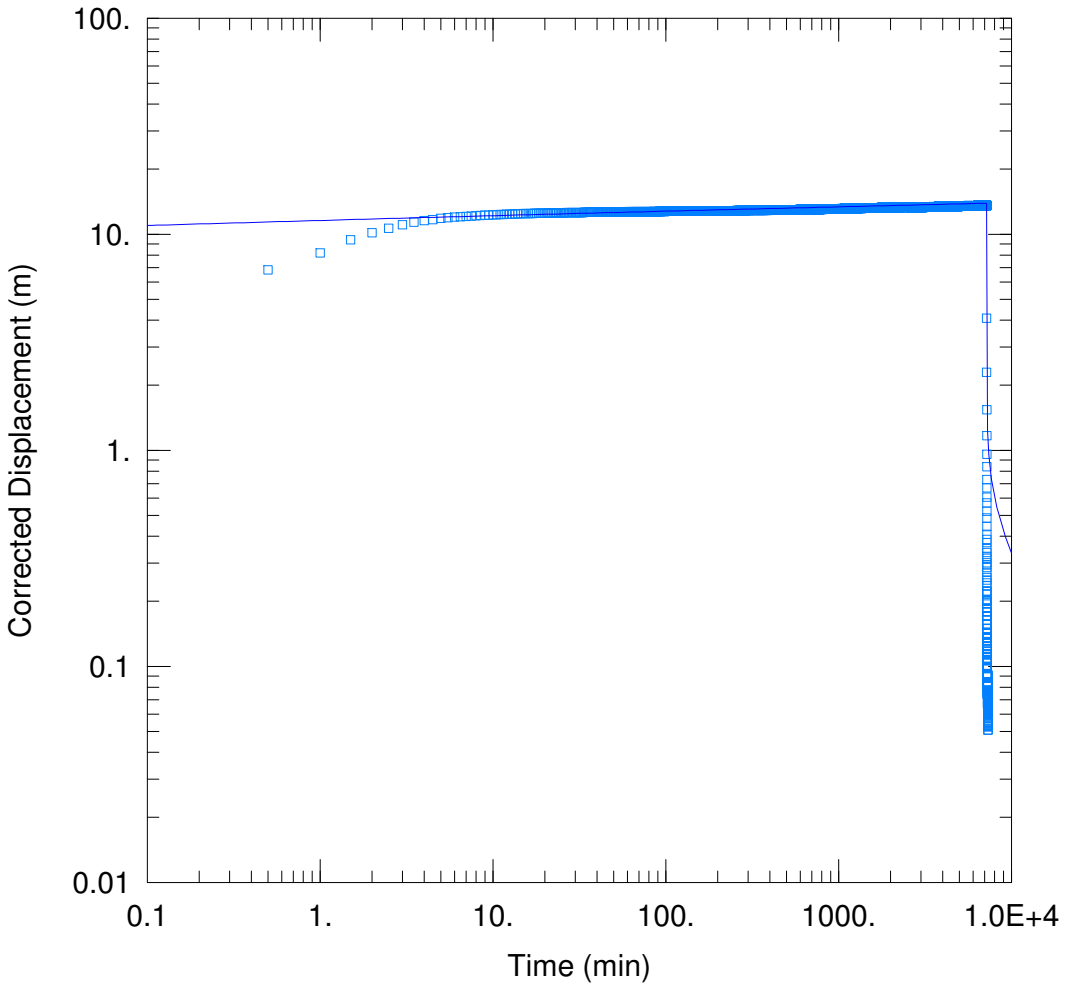
Observation Wells

Well Name	X (m)	Y (m)
MDPB0012	655677	7551804

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 843.6 m^2/day S = 1.576E-19



WELL TEST ANALYSIS

Data Set: F:\171\2.TECH\Test Pumping\MDPB0012\MDPB0012.aqt
Date: 10/10/19 Time: 13:17:52

PROJECT INFORMATION

Company: AQ2
Client: HPPL
Project: 171
Location: Mulga Downs
Test Well: MDPB0012

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0012	655677	7551804

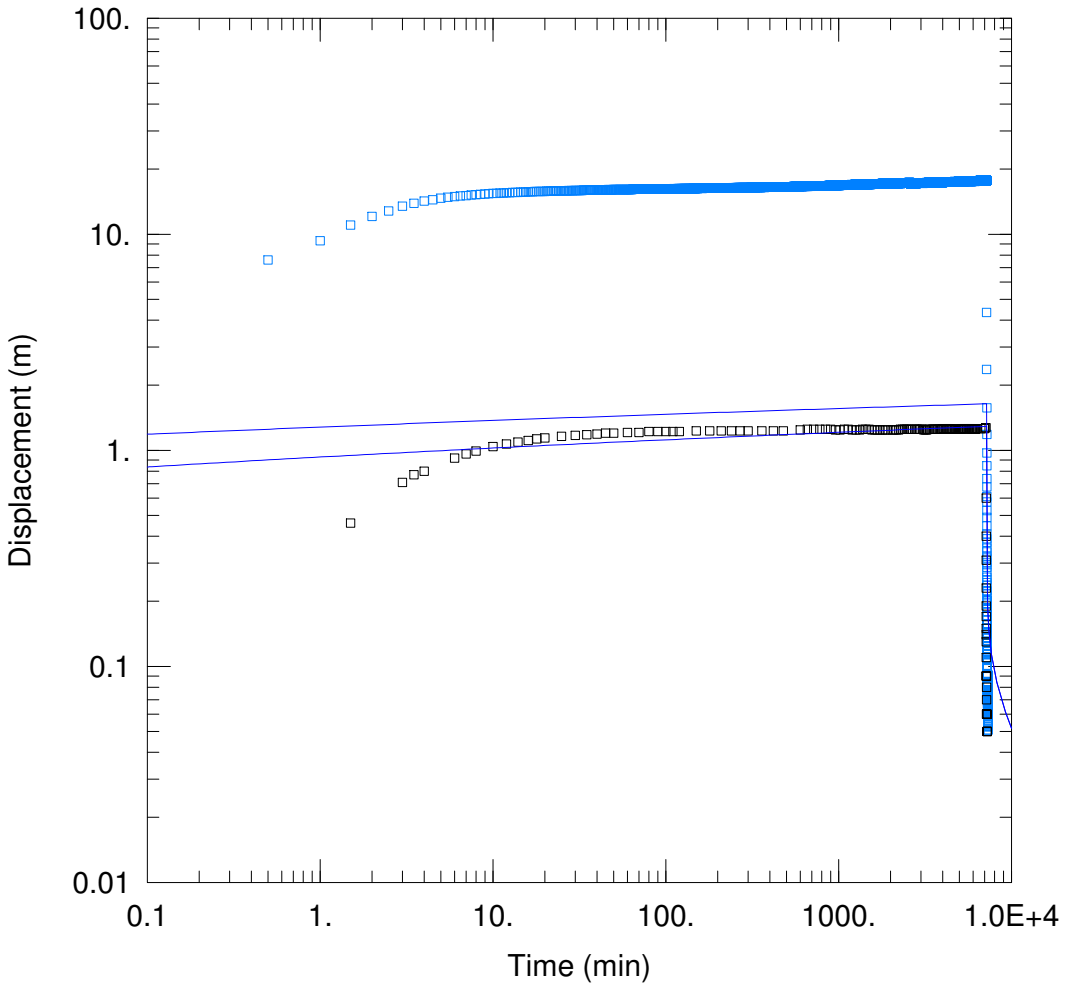
Observation Wells

Well Name	X (m)	Y (m)
MDPB0012	655677	7551804

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 785.7 m^2/day
S = 2.185E-18
Kz/Kr = 0.1
b = 38. m



WELL TEST ANALYSIS

Data Set: F:\171\2.TECH\Test Pumping\MDPB0012\MDPB0012.aqt
Date: 02/14/20 Time: 14:57:33

PROJECT INFORMATION

Company: AQ2
Client: HPPL
Project: 171
Location: Mulga Downs
Test Well: MDPB0012

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0012	655667.2827	551805.066

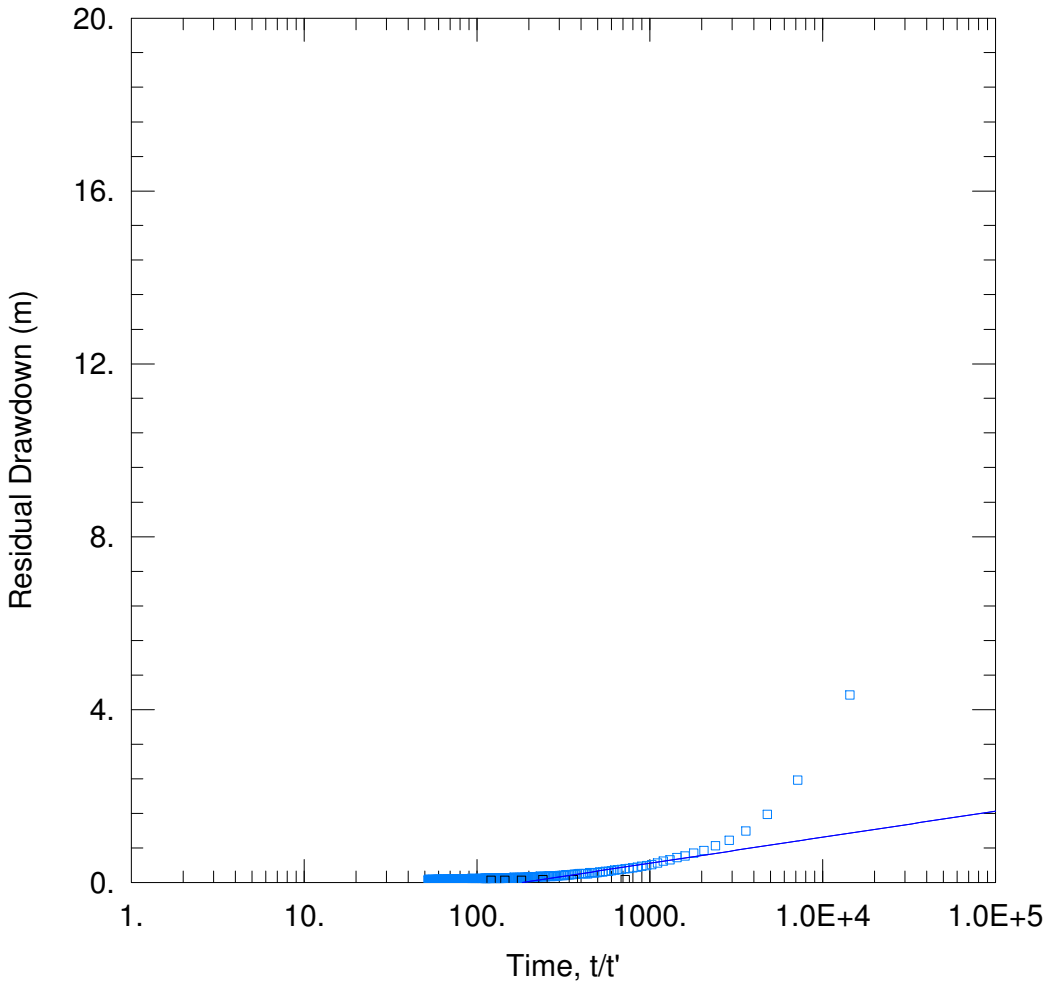
Observation Wells

Well Name	X (m)	Y (m)
MDPB0012	655667.2827	551805.066
MDPZ7449B	655656.9497	551794.501

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 5077.6 m^2/day
S = 4.114E-12
Kz/Kr = 0.1
b = 38. m



WELL TEST ANALYSIS

Data Set: F:\171\2.TECH\Test Pumping\MDPB0012\MDPB0012.aqt
Date: 02/14/20 Time: 14:56:13

PROJECT INFORMATION

Company: AQ2
Client: HPPL
Project: 171
Location: Mulga Downs
Test Well: MDPB0012

AQUIFER DATA

Saturated Thickness: 38. m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0012	655667.282	7551805.066

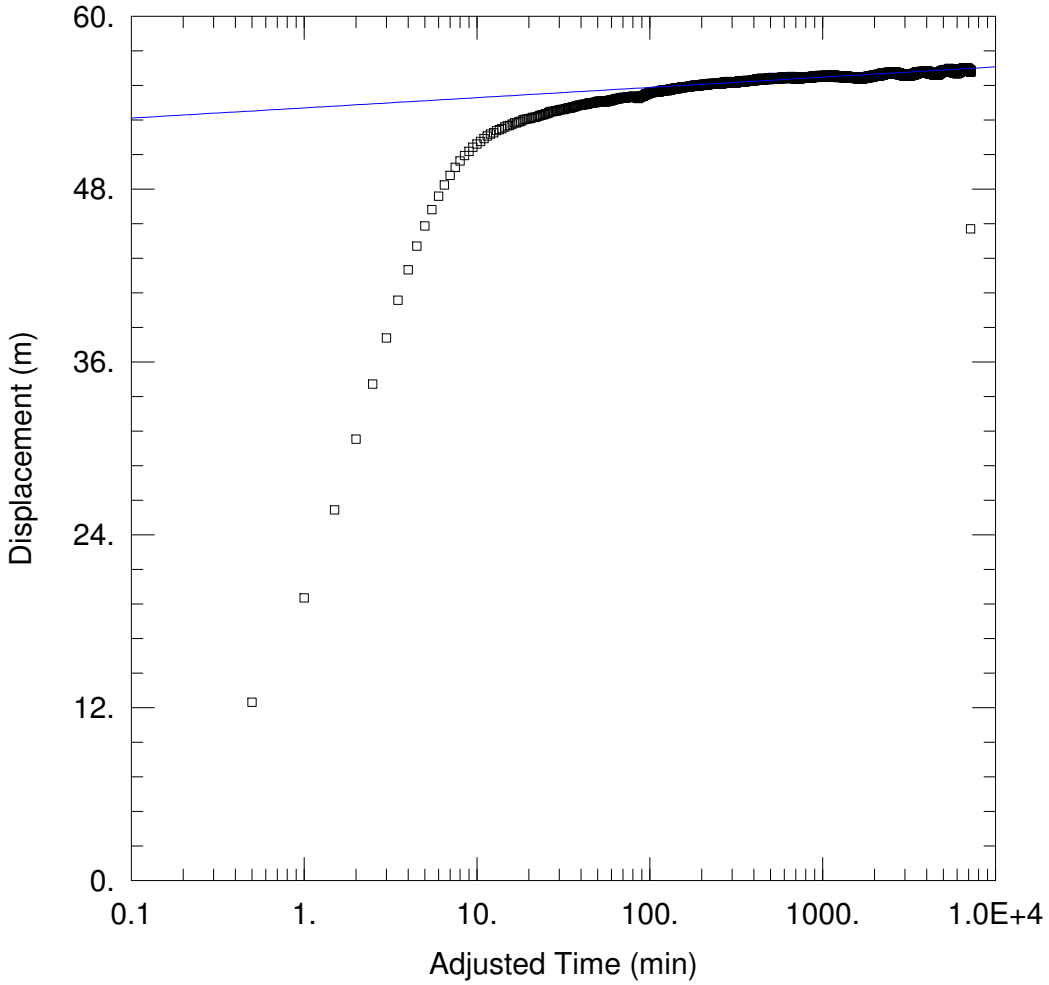
Observation Wells

Well Name	X (m)	Y (m)
MDPB0012	655667.282	7551805.066
MDPZ7449B	655656.949	7551794.501

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 788.9 m^2/day S/S' = 183.9



WELL TEST ANALYSIS

Data Set: F:\171\2.TECH\Test Pumping\MDPB0013\MDPB0013.aqt
Date: 10/10/19 Time: 13:18:25

PROJECT INFORMATION

Company: AQ2
Client: HPPL
Project: 171
Location: Mulga Downs
Test Well: MDPB0013

AQUIFER DATA

Saturated Thickness: 58. m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0013	663199	7547991

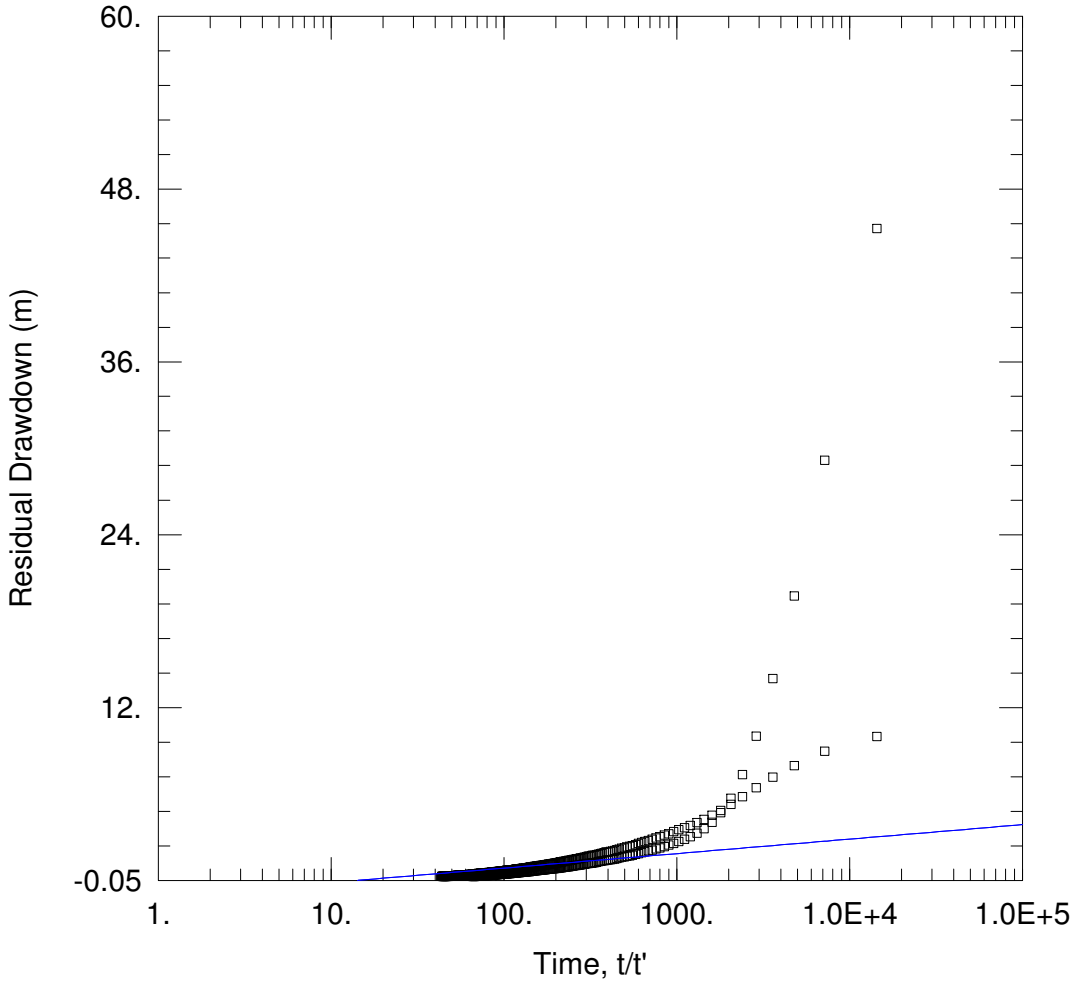
Observation Wells

Well Name	X (m)	Y (m)
MDPB0013	663199	7547991

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Jacob

T = 556.7 m^2/day S = 8.067E-75



WELL TEST ANALYSIS

Data Set: F:\171\2.TECH\Test Pumping\MDPB0013\MDPB0013.aqt
Date: 02/14/20 Time: 14:44:34

PROJECT INFORMATION

Company: AQ2
Client: HPPL
Project: 171
Location: Mulga Downs
Test Well: MDPB0013

AQUIFER DATA

Saturated Thickness: 58. m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0013	656694.104	7548123.999

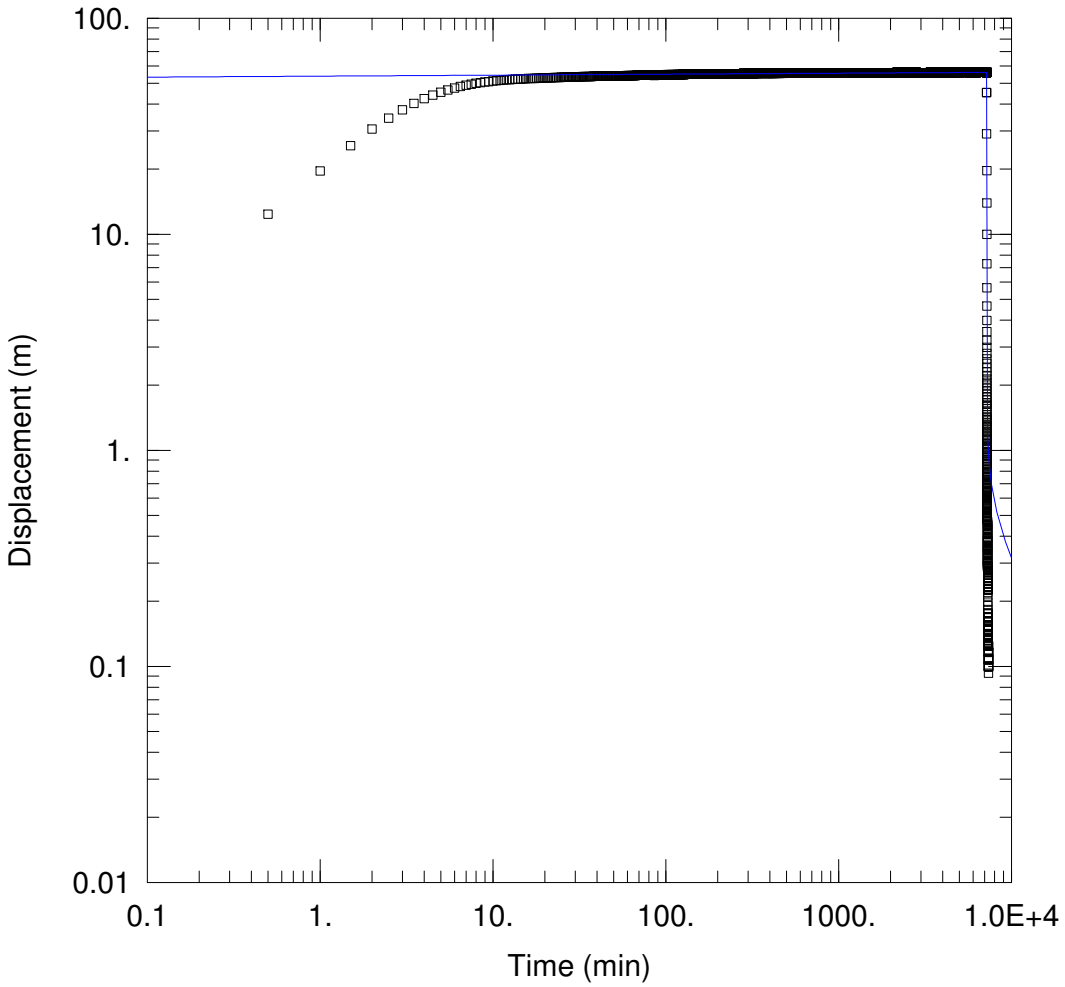
Observation Wells

Well Name	X (m)	Y (m)
MDPB0013	656694.104	7548123.999
MDPZ7460A	663200.832	7547990.12

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 393.3 m^2/day S/S' = 15.92



WELL TEST ANALYSIS

Data Set: F:\171\2.TECH\Test Pumping\MDPB0013\MDPB0013.aqt
Date: 10/10/19 Time: 13:19:30

PROJECT INFORMATION

Company: AQ2
Client: HPPL
Project: 171
Location: Mulga Downs
Test Well: MDPB0013

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0013	663199	7547991

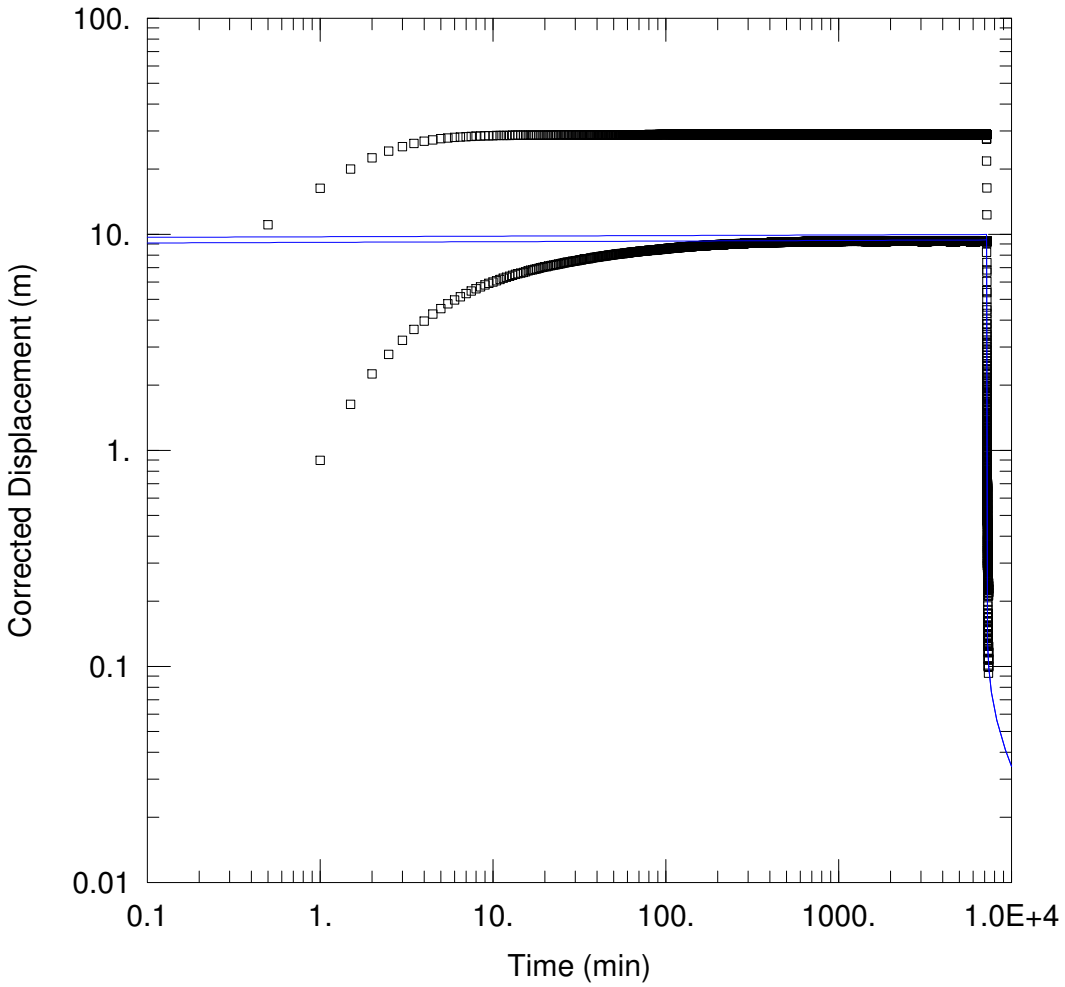
Observation Wells

Well Name	X (m)	Y (m)
▫ MDPB0013	663199	7547991

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 688.9 m^2/day
Kz/Kr = 0.1
S = 4.393E-93
b = 58. m



WELL TEST ANALYSIS

Data Set: F:\171\2.TECH\Test Pumping\MDPB0013\MDPB0013.aqt
Date: 02/14/20 Time: 14:46:05

PROJECT INFORMATION

Company: AQ2
Client: HPPL
Project: 171
Location: Mulga Downs
Test Well: MDPB0013

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0013	656694.104	7548123.999

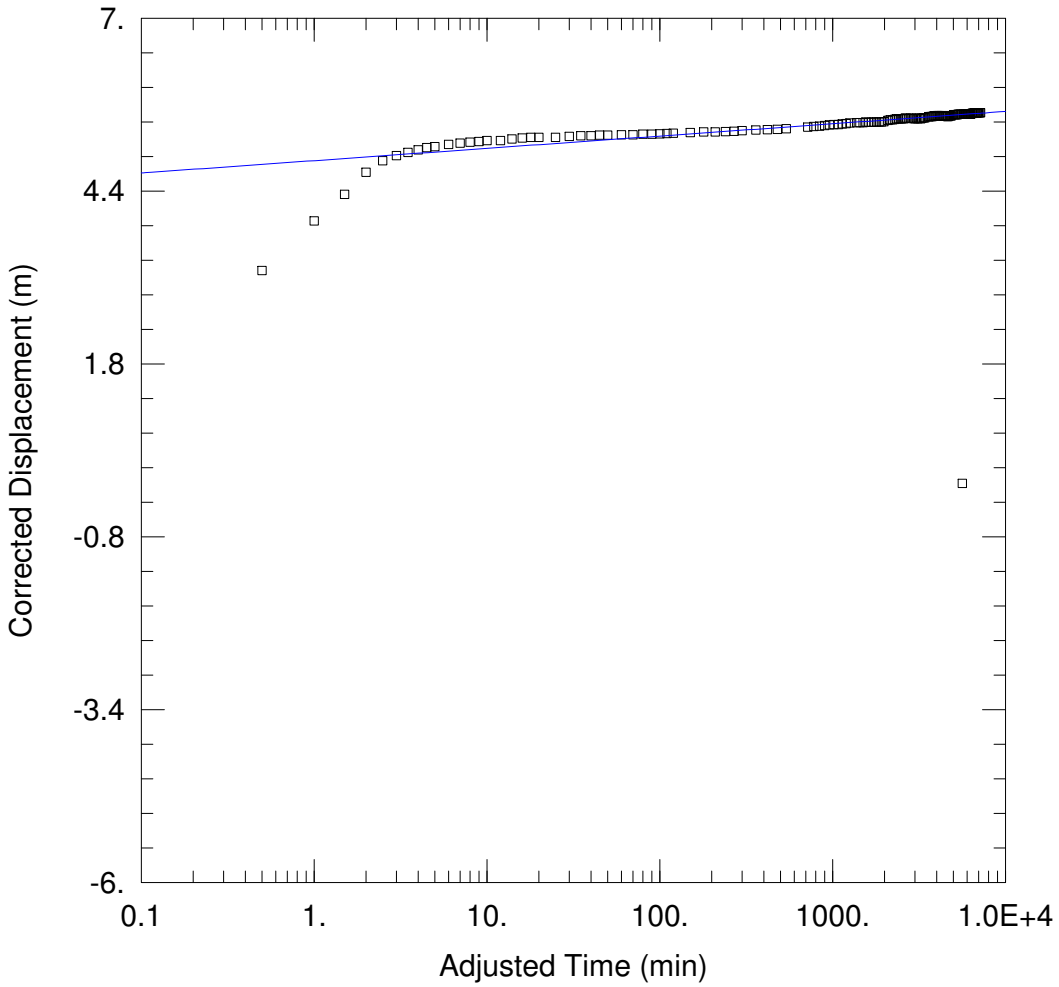
Observation Wells

Well Name	X (m)	Y (m)
MDPB0013	656694.104	7548123.999
MDPZ7460A	663200.832	7547990.12

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 6361.4 m^2/day
S = 1.067E-154
Kz/Kr = 0.1
b = 58. m



WELL TEST ANALYSIS

Data Set: F:\171\2.TECH\Test Pumping\MDPB0014\MDPB0014.aqt
Date: 10/10/19 Time: 13:36:35

PROJECT INFORMATION

Company: AQ2
Client: HPPL
Project: 171
Location: Mulga Downs
Test Well: MDPB0014

AQUIFER DATA

Saturated Thickness: 30. m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0014	656730	7548159

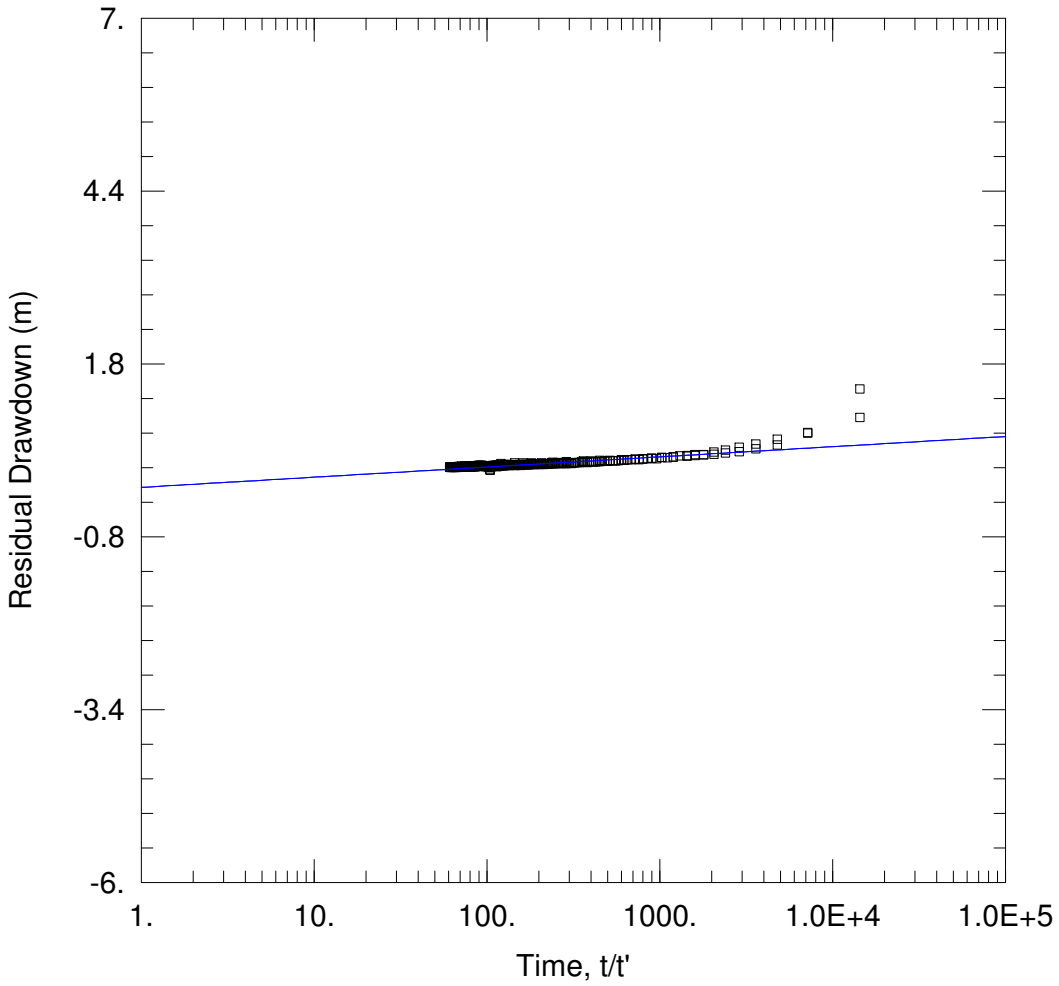
Observation Wells

Well Name	X (m)	Y (m)
▫ MDPB0014	656730	7548159

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 1881.8 m^2/day S = 4.26E-25



WELL TEST ANALYSIS

Data Set: F:\171\2.TECH\Test Pumping\MDPB0014\MDPB0014.aqt
Date: 02/14/20 Time: 10:54:03

PROJECT INFORMATION

Company: AQ2
Client: HPPL
Project: 171
Location: Mulga Downs
Test Well: MDPB0014

AQUIFER DATA

Saturated Thickness: 30. m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0014	656730	7548159

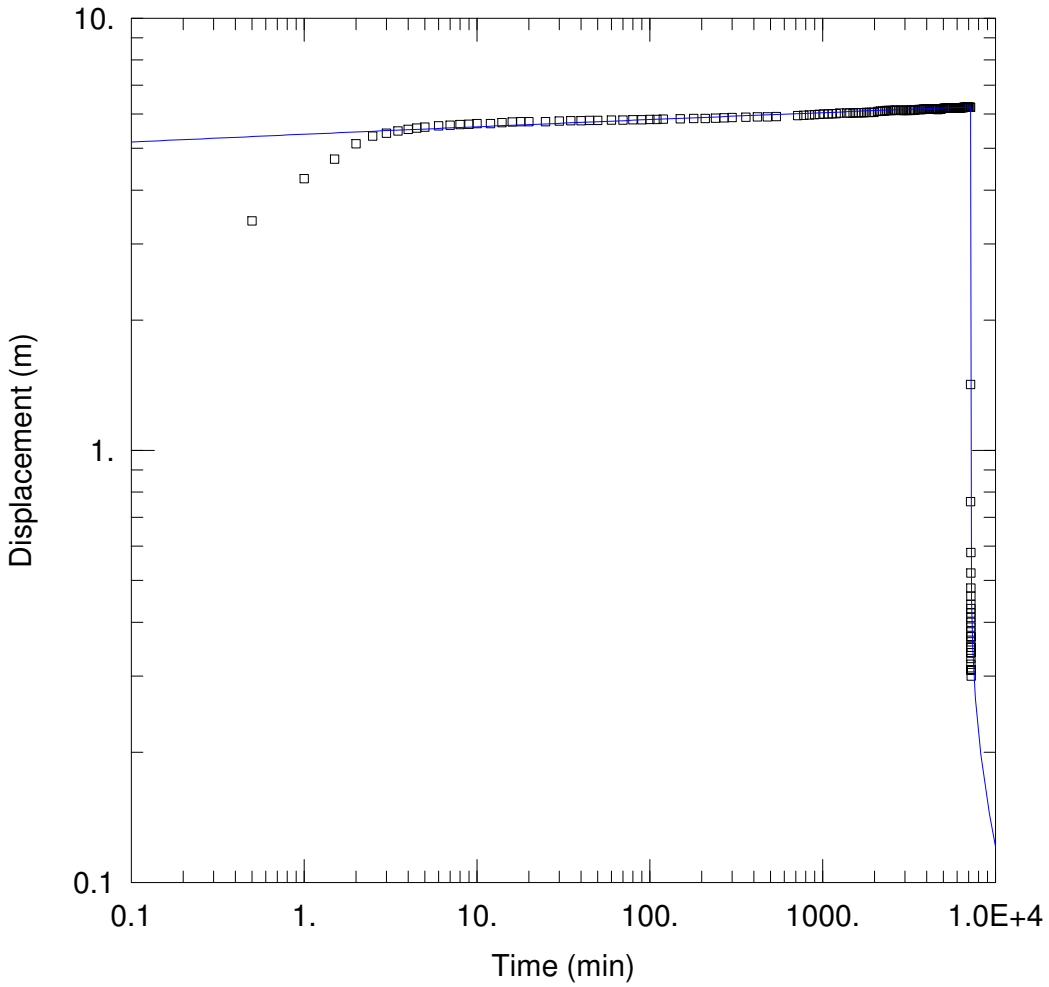
Observation Wells

Well Name	X (m)	Y (m)
MDPB0014	656730	7548159
MDPZ7457C	656725.7	7548165.988

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 2277.7 m^2/day S/S' = 2.401



WELL TEST ANALYSIS

Data Set:
Date: 10/10/19 Time: 13:34:44

PROJECT INFORMATION

Company: AQ2
Client: HPPL
Project: 171
Location: Mulga Downs
Test Well: MDPB0014

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0014	656730	7548159

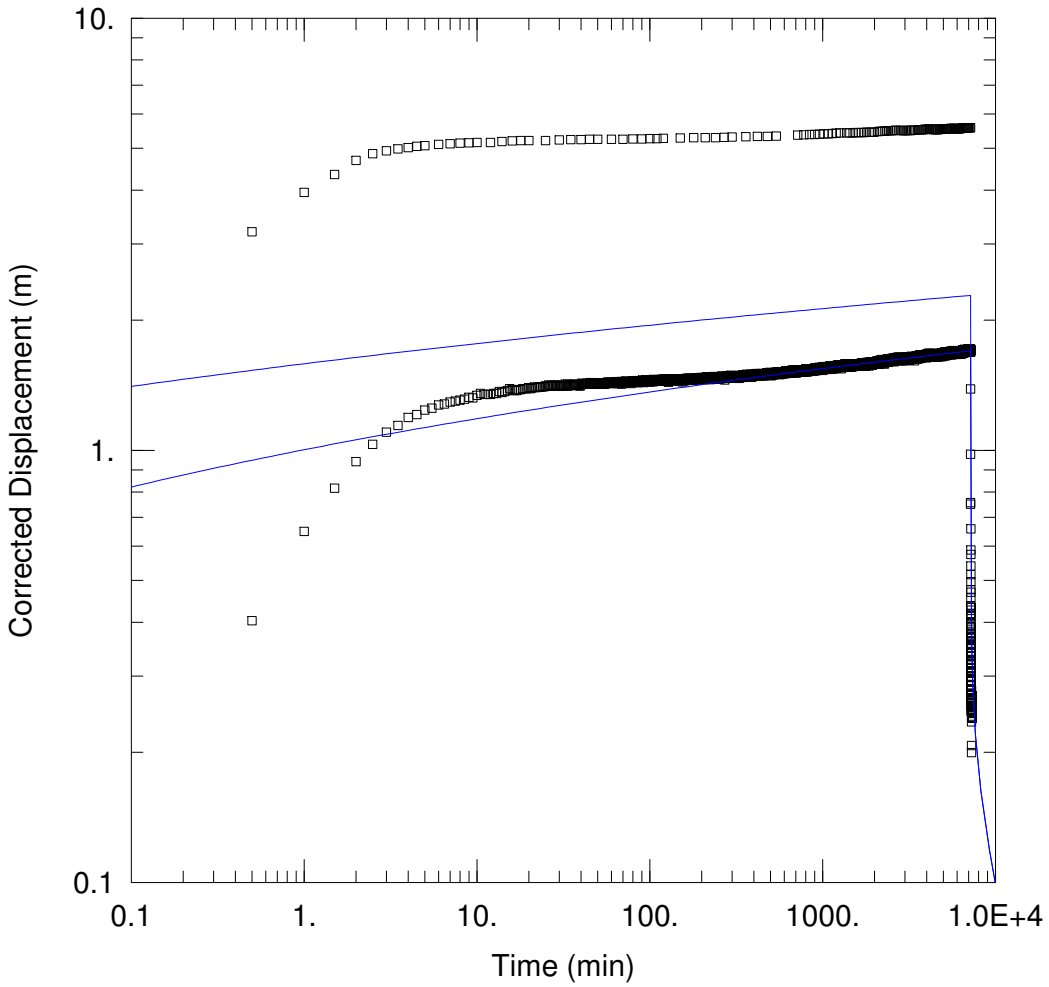
Observation Wells

Well Name	X (m)	Y (m)
▫ MDPB0014	656730	7548159

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 1590.9 m^2/day
S = 1.554E-23
Kz/Kr = 0.1
b = 30. m



WELL TEST ANALYSIS

Data Set: F:\171\2.TECH\Test Pumping\MDPB0014\MDPB0014.aqt
Date: 02/14/20 Time: 10:53:13

PROJECT INFORMATION

Company: AQ2
Client: HPPL
Project: 171
Location: Mulga Downs
Test Well: MDPB0014

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0014	656730	7548159

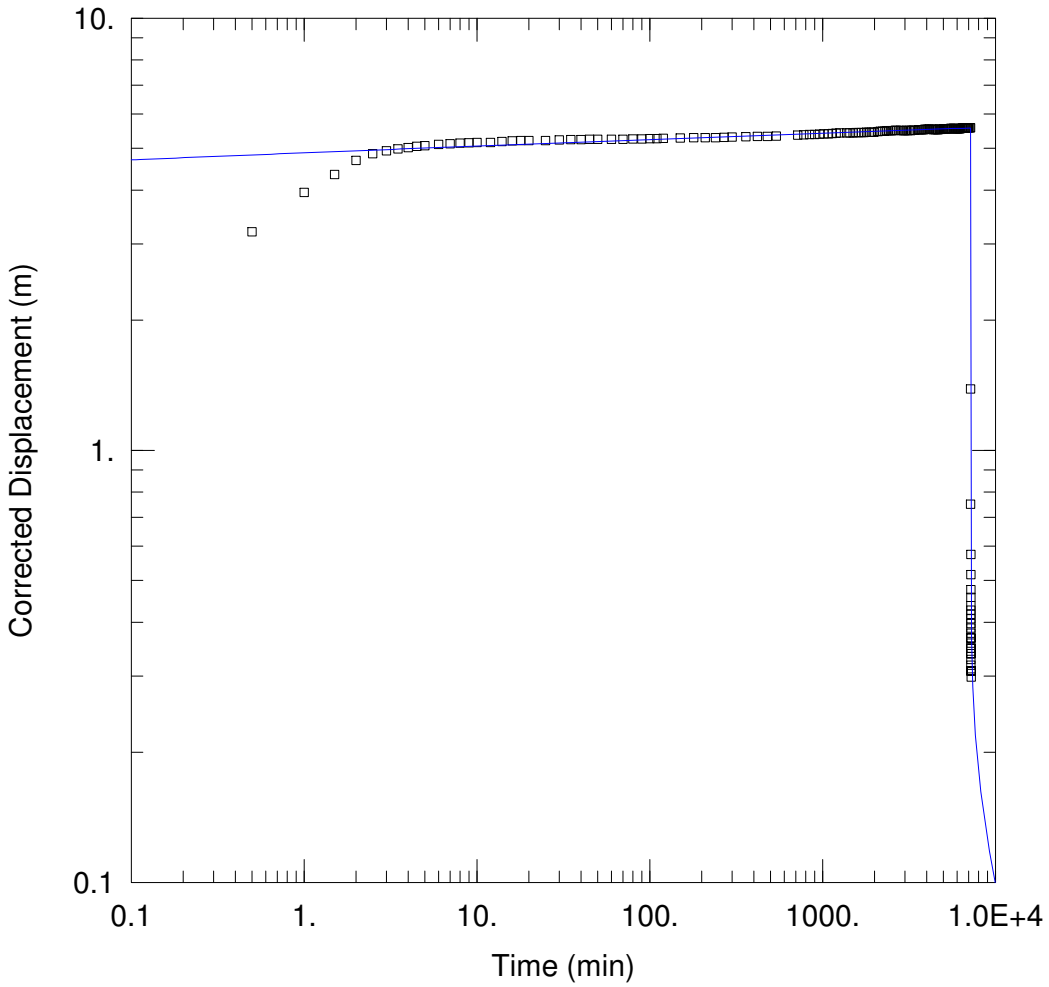
Observation Wells

Well Name	X (m)	Y (m)
▫ MDPB0014	656730	7548159
▫ MDPZ7457C	656725.7	7548165.988

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 1928.2 m^2/day
S = 1.255E-7
Kz/Kr = 0.1
b = 30. m



WELL TEST ANALYSIS

Data Set: F:\171\2.TECH\Test Pumping\MDPB0014\MDPB0014.aqt
Date: 10/10/19 Time: 13:35:56

PROJECT INFORMATION

Company: AQ2
Client: HPPL
Project: 171
Location: Mulga Downs
Test Well: MDPB0014

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0014	656730	7548159

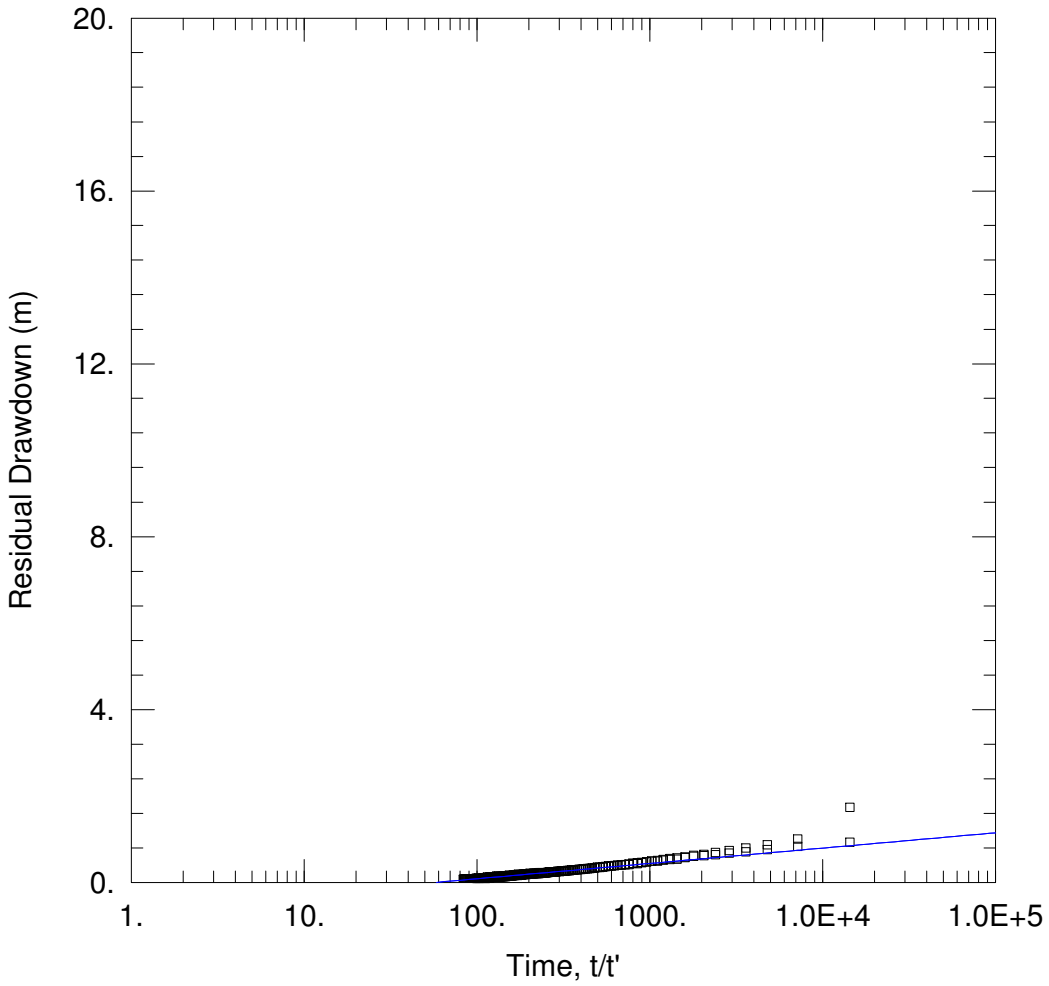
Observation Wells

Well Name	X (m)	Y (m)
▫ MDPB0014	656730	7548159

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 1941.1 m^2/day
S = 4.932E-26
Kz/Kr = 0.1
b = 30. m



WELL TEST ANALYSIS

Data Set: F:\171\2.TECH\Test Pumping\MDPB0015\MDPB0015.aqt
Date: 02/14/20 Time: 10:56:58

PROJECT INFORMATION

Company: AQ2
Client: HPPL
Project: 171
Location: Mulga Downs
Test Well: MDPB0015

AQUIFER DATA

Saturated Thickness: 20. m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0015	651329	7545798

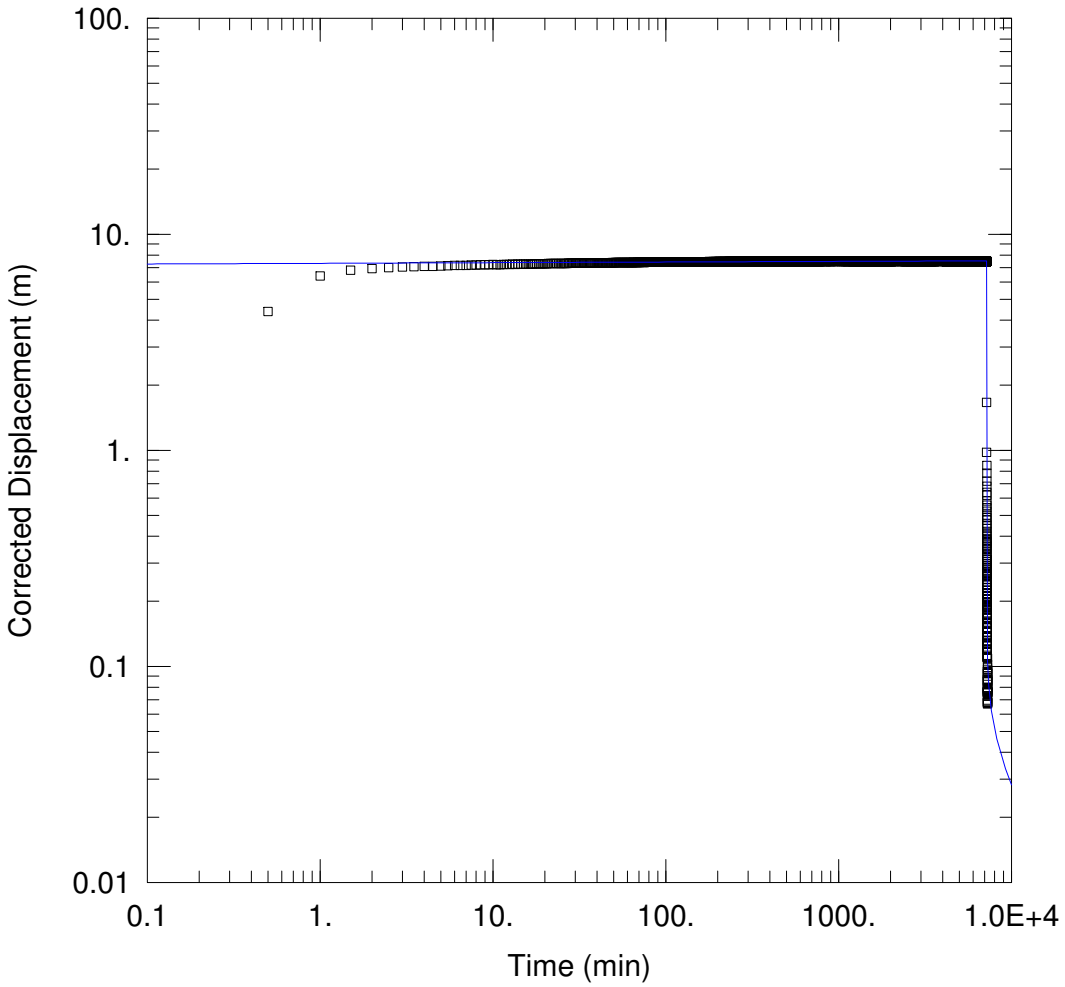
Observation Wells

Well Name	X (m)	Y (m)
MDPB0015	651329	7545798
MDPZ7452B	651336.383	7545806.109

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 1784.9 m^2/day S/S' = 58.19



WELL TEST ANALYSIS

Data Set:
Date: 10/10/19 Time: 13:24:32

PROJECT INFORMATION

Company: AQ2
Client: HPPL
Project: 171
Location: Mulga Downs
Test Well: MDPB0015

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0015	651329	7545798

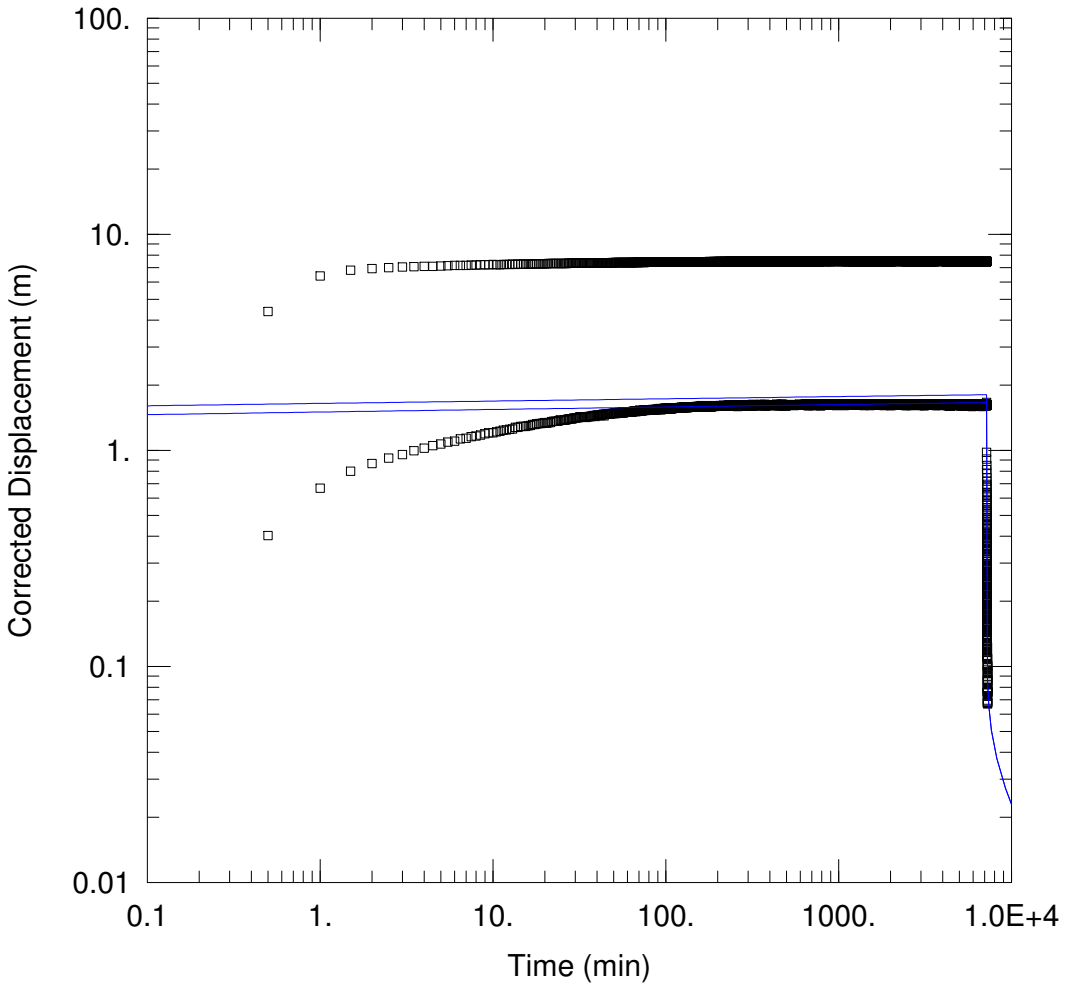
Observation Wells

Well Name	X (m)	Y (m)
▫ MDPB0015	651329	7545798

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 1.238E+4 m^2/day
S = 2.111E-141
Kz/Kr = 0.1
b = 20. m



WELL TEST ANALYSIS

Data Set: F:\171\2.TECH\Test Pumping\MDPB0015\MDPB0015.aqt
Date: 02/14/20 Time: 14:03:12

PROJECT INFORMATION

Company: AQ2
Client: HPPL
Project: 171
Location: Mulga Downs
Test Well: MDPB0015

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0015	651329	7545798

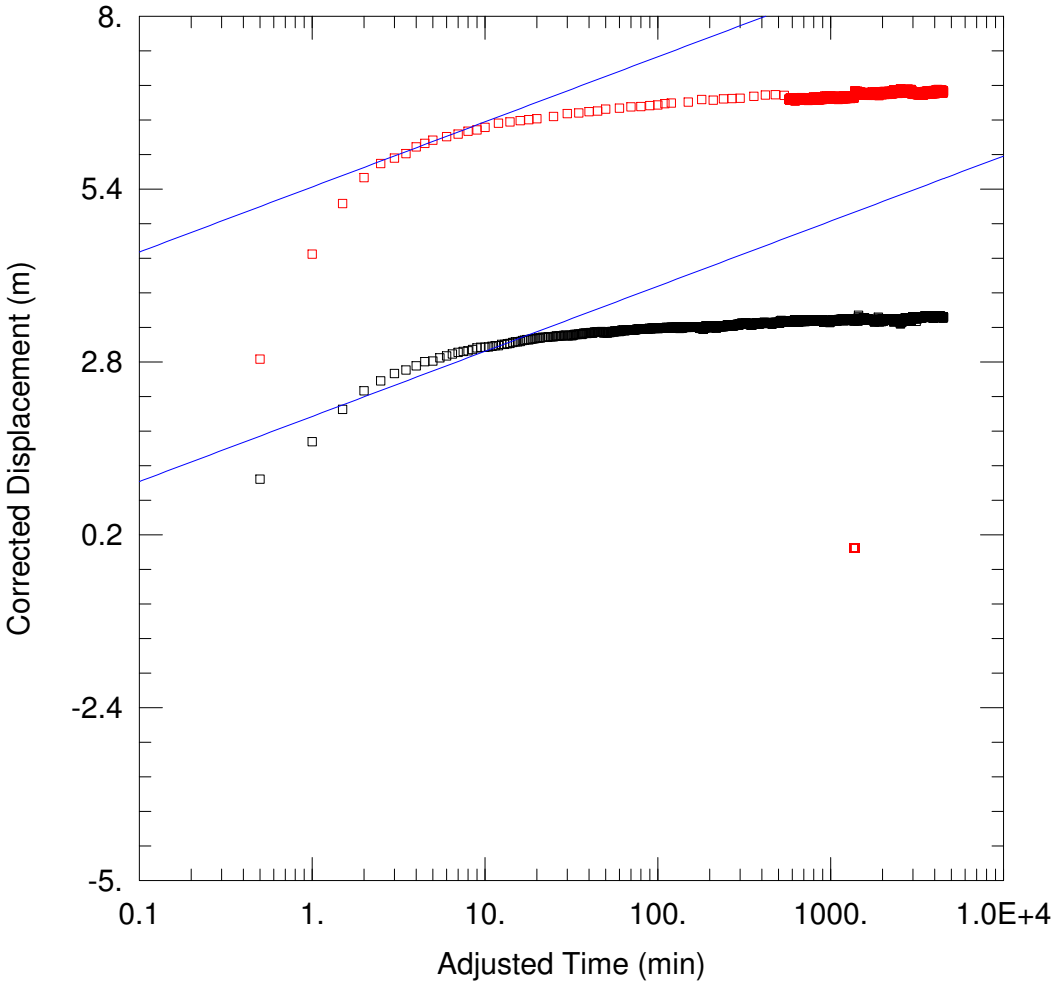
Observation Wells

Well Name	X (m)	Y (m)
▫ MDPB0015	651329	7545798
▫ MDPZ7452B	651336.383	7545806.109

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 1.525E+4 m^2/day
S = 1.246E-37
Kz/Kr = 0.1
b = 20. m



WELL TEST ANALYSIS

Data Set: C:\Users\EJBolton\Documents\Drafts etc\171\Task J\Test Pumping\MDPB0016_CJ.aqt
Date: 03/17/22 Time: 09:53:29

PROJECT INFORMATION

Company: AQ2
Client: Roy Hill
Project: 171J
Location: Mulga East
Test Well: MDPB0016
Test Date: 27/11/2021

AQUIFER DATA

Saturated Thickness: 78. m Anisotropy Ratio (Kz/Kr): 1.521E+4

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0016	657319	7550025

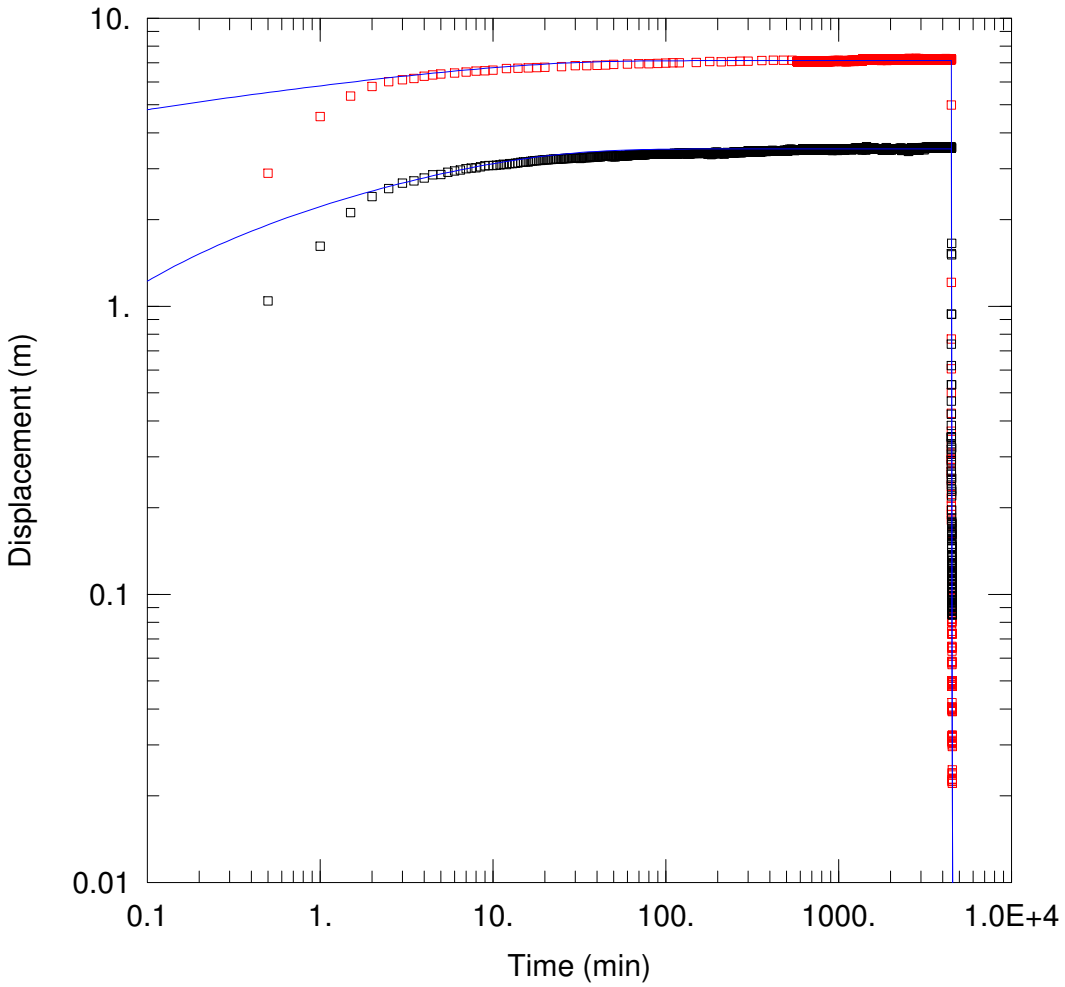
Observation Wells

Well Name	X (m)	Y (m)
MDPB0016	657319	7550025
MDPZ7469B	657307.533	7550026.665

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 646.8 m^2/day S = 7.16E-5



WELL TEST ANALYSIS

Data Set: F:\171\2.TECH\PFS Test Pumping\MDPB0016\MDPB0016.aqt
Date: 01/07/22 Time: 14:44:48

PROJECT INFORMATION

Company: AQ2
Client: Roy Hill
Project: 171J
Location: Mulga East
Test Well: MDPB0016
Test Date: 27/11/2021

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0016	657319	7550025

Observation Wells

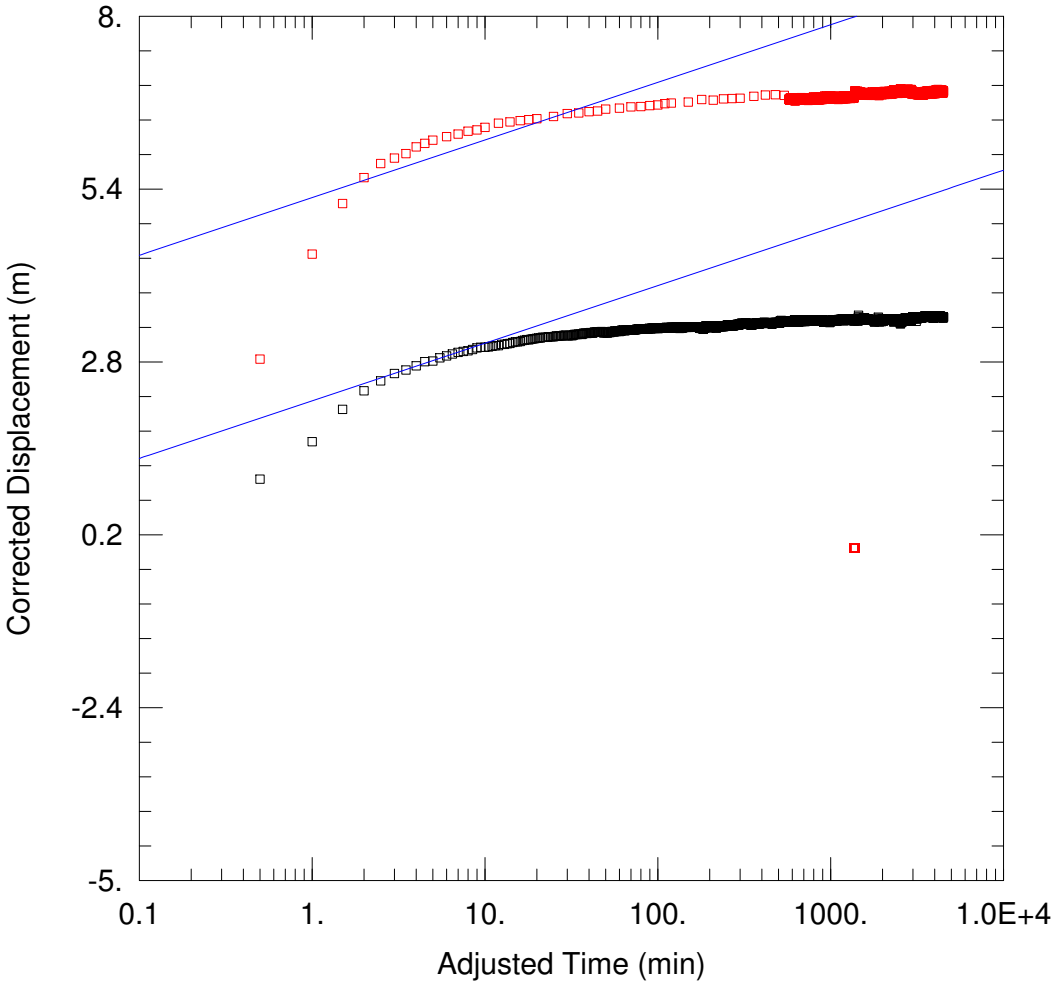
Well Name	X (m)	Y (m)
MDPB0016	657319	7550025
MDPZ7469B	657307.5337	7550026.665

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush-Jacob

T = 619.4 m^2/day
1/B = 0.001856 m^{-1}
b = 78. m

S = 4.756E-5
Kz/Kr = 0.1



WELL TEST ANALYSIS

Data Set: C:\...\MDPB0016_CJ_7459B.aqt
Date: 03/17/22 Time: 09:50:38

PROJECT INFORMATION

Company: AQ2
Client: Roy Hill
Project: 171J
Location: Mulga East
Test Well: MDPB0016
Test Date: 27/11/2021

AQUIFER DATA

Saturated Thickness: 78. m Anisotropy Ratio (Kz/Kr): 1.521E+4

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0016	657319	7550025

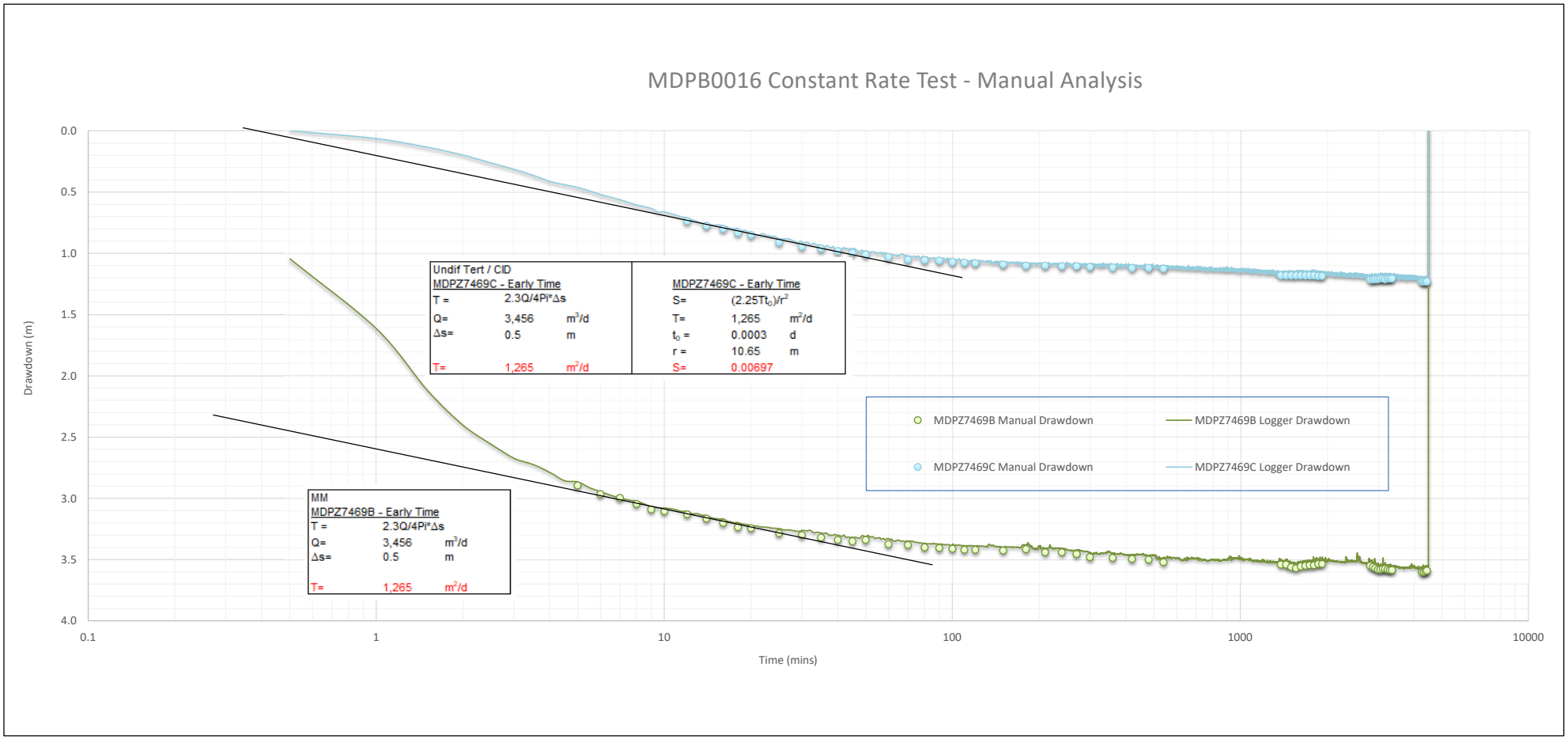
Observation Wells

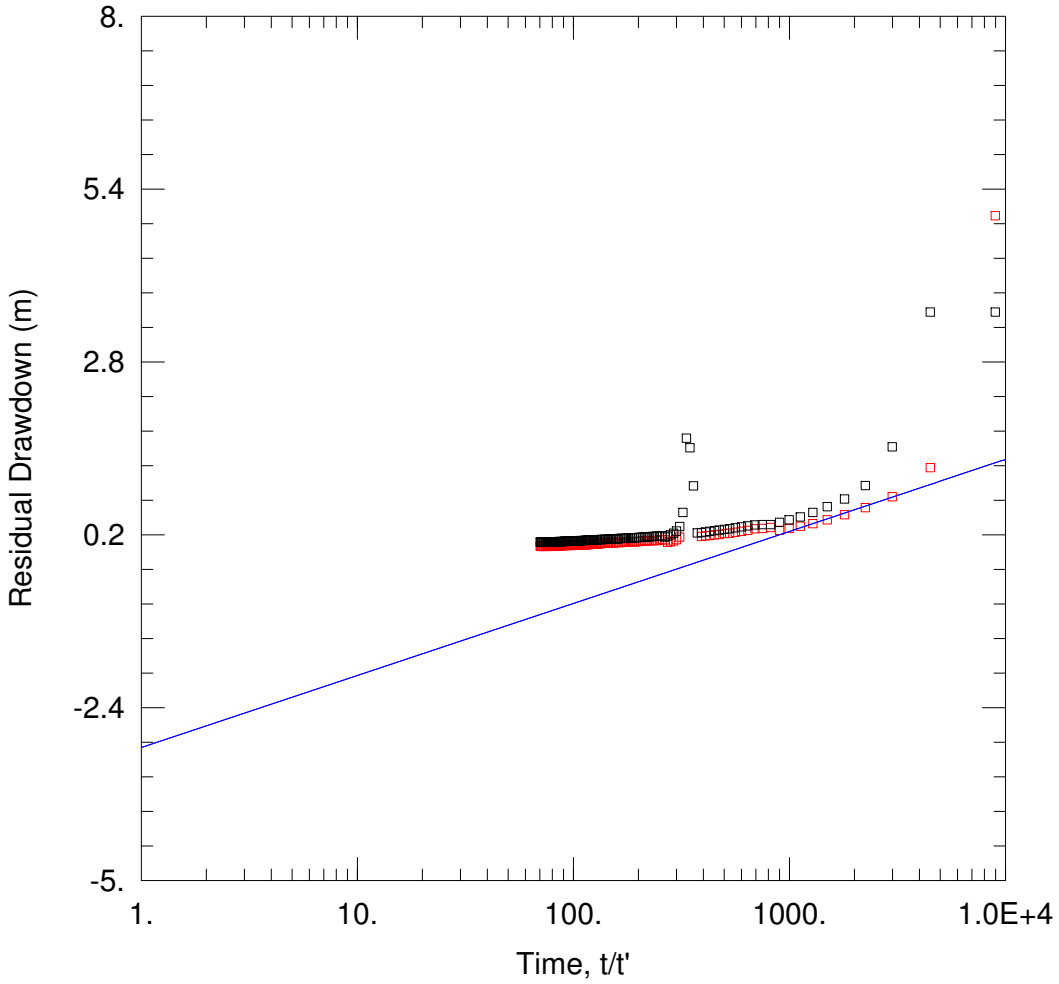
Well Name	X (m)	Y (m)
MDPB0016	657319	7550025
MDPZ7469B	657307.533	7550026.665

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 730.8 m^2/day S = 2.366E-5


MDPB0016 Constant Rate Test - Manual Analysis
Drawdown (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
0.1
1
10
100
1000
10000
Time (mins)
Undif Tert / CID
MDPZ7469C - Early Time
T = 2.3Q/4Pi*Δs
Q= 3,456 m³/d
Δs= 0.5 m
T= 1,265 m²/d
MDPZ7469C - Early Time
S= (2.25Tt0)/r²
T= 1,265 m²/d
t0 = 0.0003 d
r = 10.65 m
S= 0.00697
MM
MDPZ7469B - Early Time
T = 2.3Q/4Pi*Δs
Q= 3,456 m³/d
Δs= 0.5 m
T= 1,265 m²/d
MDPZ7469B Manual Drawdown
MDPZ7469B Logger Drawdown
MDPZ7469C Manual Drawdown
MDPZ7469C Logger Drawdown



WELL TEST ANALYSIS

Data Set: C:\Users\EJBolton\Documents\Drafts etc\171\Task J\Test Pumping\MDPB0016_Rec.aqt
Date: 03/17/22 Time: 09:59:00

PROJECT INFORMATION

Company: AQ2
Client: Roy Hill
Project: 171J
Location: Mulga East
Test Well: MDPB0016
Test Date: 27/11/2021

AQUIFER DATA

Saturated Thickness: 78. m Anisotropy Ratio (Kz/Kr): 1.521E+4

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0016	657319	7550025

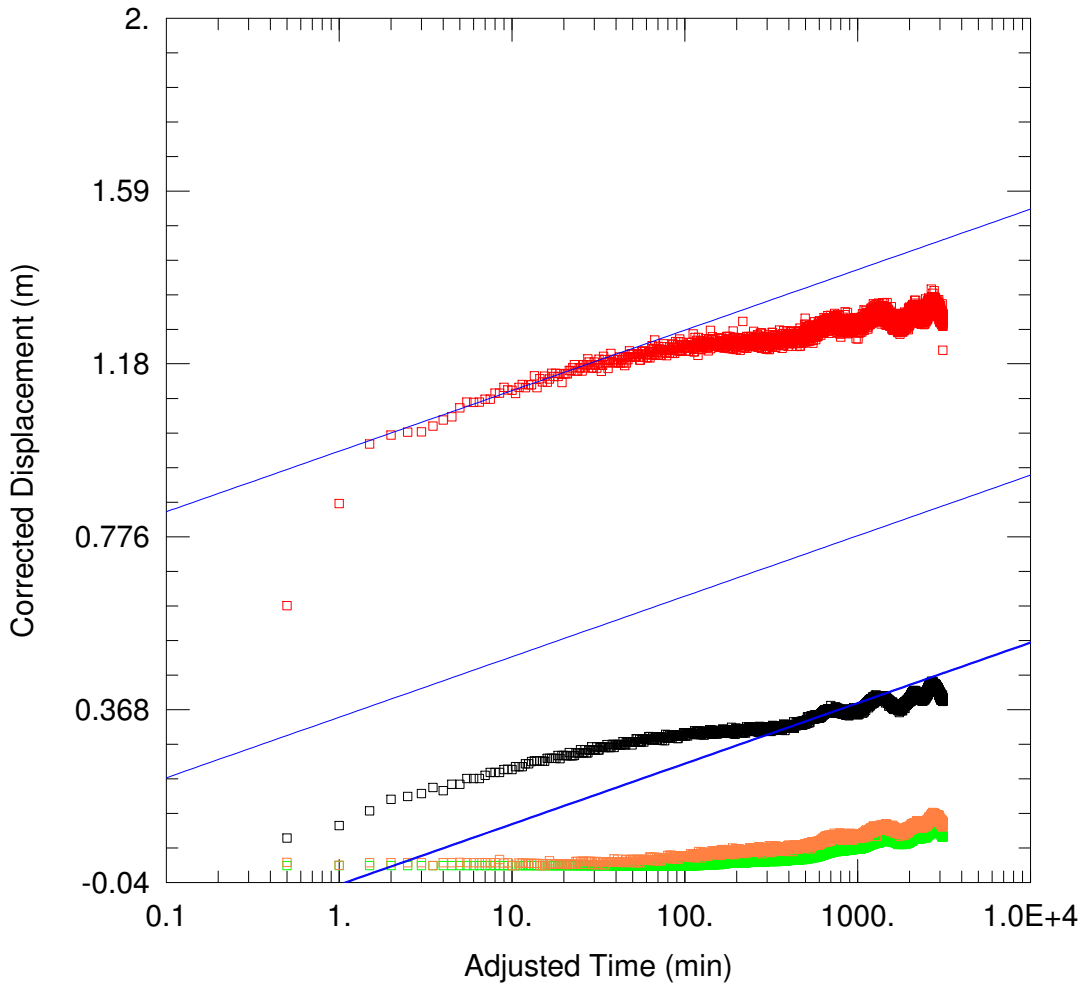
Observation Wells

Well Name	X (m)	Y (m)
MDPB0016	657319	7550025
MDPZ7469B	657307.533	7550026.665

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 584.6 m^2/day S/S' = 590.1



WELL TEST ANALYSIS

Data Set: C:\Users\EJBolton\Documents\Drafts etc\171\Task J\Test Pumping\MDPB0017_CJ_early.aqt
Date: 03/17/22 Time: 10:04:52

PROJECT INFORMATION

Company: AQ2
Client: Roy Hill
Project: 171J
Location: Mulga East
Test Well: MDPB0017

AQUIFER DATA

Saturated Thickness: 88. m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0017	666392	7548457

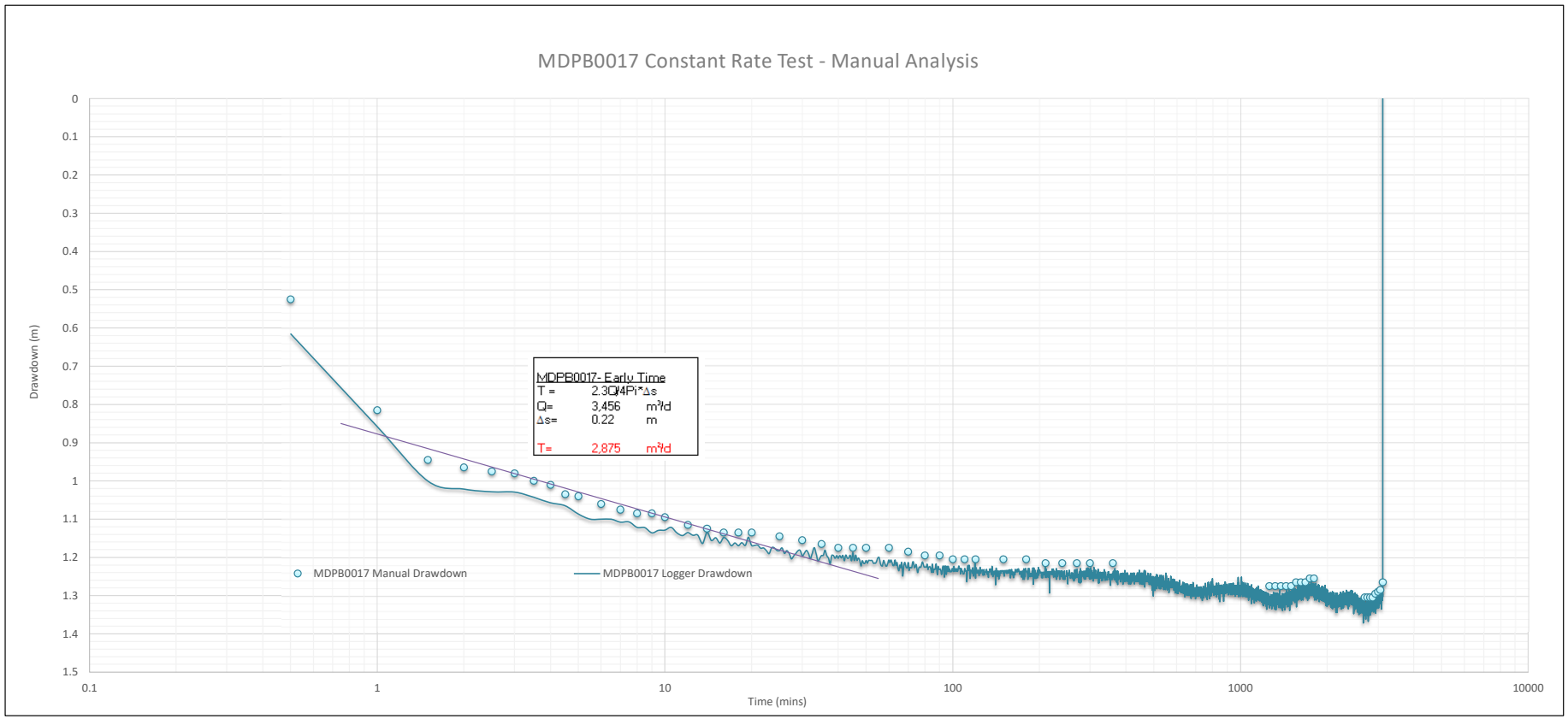
Observation Wells

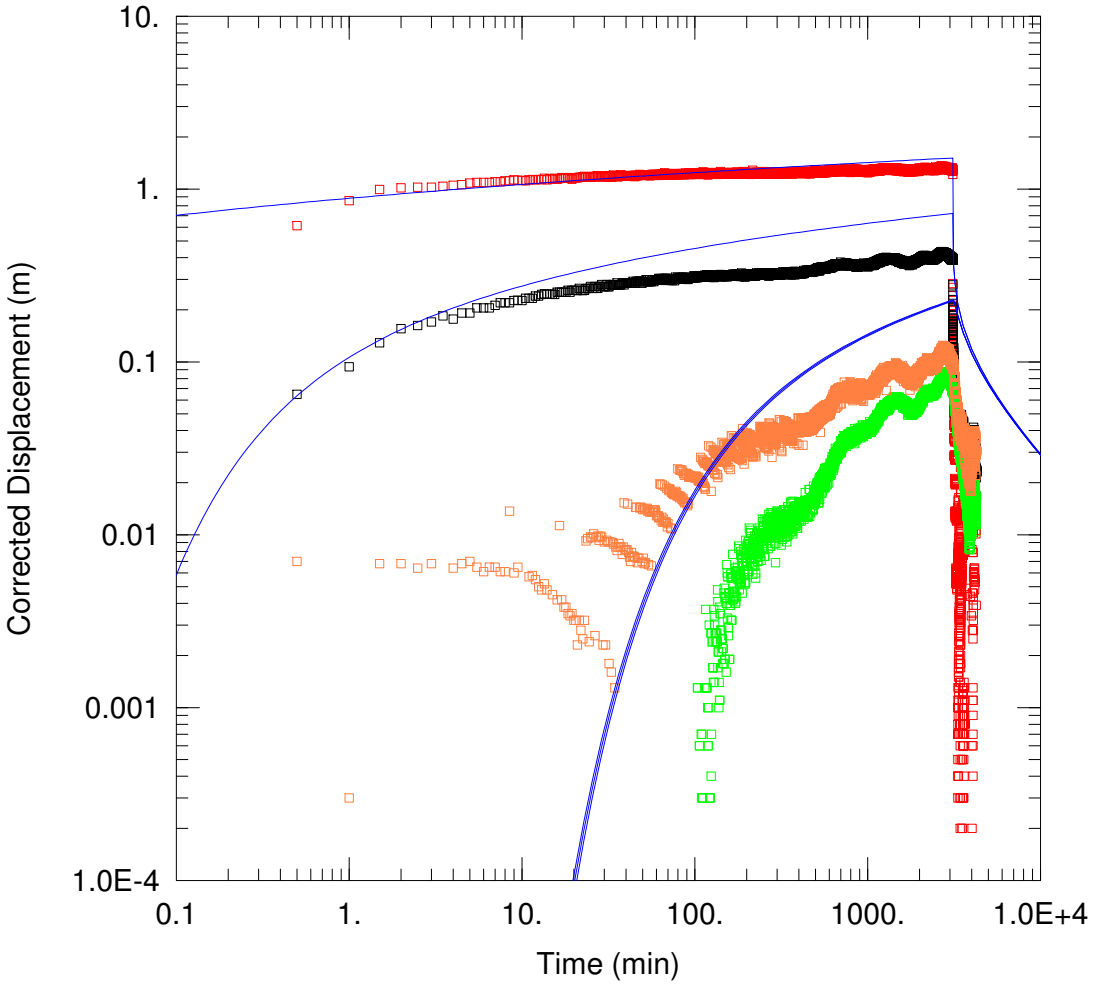
Well Name	X (m)	Y (m)
MDPB0017	666392	7548457
MDPZ9204	666360.69	7548461
MDPZ7456A	665850.759	7547906.099
MDPZ7456B	665865.231	7547917.735
MDPZ7456C	665858.433	7547912.293

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 4433.2 m^2/day S = 2.47E-5


MDPB0017 Constant Rate Test - Manual Analysis
Drawdown (m)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
1.5
0.1
1
10
100
1000
10000
Time (mins)
MDPB0017- Early Time
T = 2.3Q/4Pi*Δs
Q= 3.456 m³/d
Δs= 0.22 m
T= 2.875 m²/d
MDPB0017 Manual Drawdown
MDPB0017 Logger Drawdown



WELL TEST ANALYSIS

Data Set: C:\Users\EJBolton\Documents\Drafts etc\171\Task J\Test Pumping\MDPB0017_Theis.aqt
Date: 03/17/22 Time: 10:18:45

PROJECT INFORMATION

Company: AQ2
Client: Roy Hill
Project: 171J
Location: Mulga East
Test Well: MDPB0017

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0017	666392	7548457

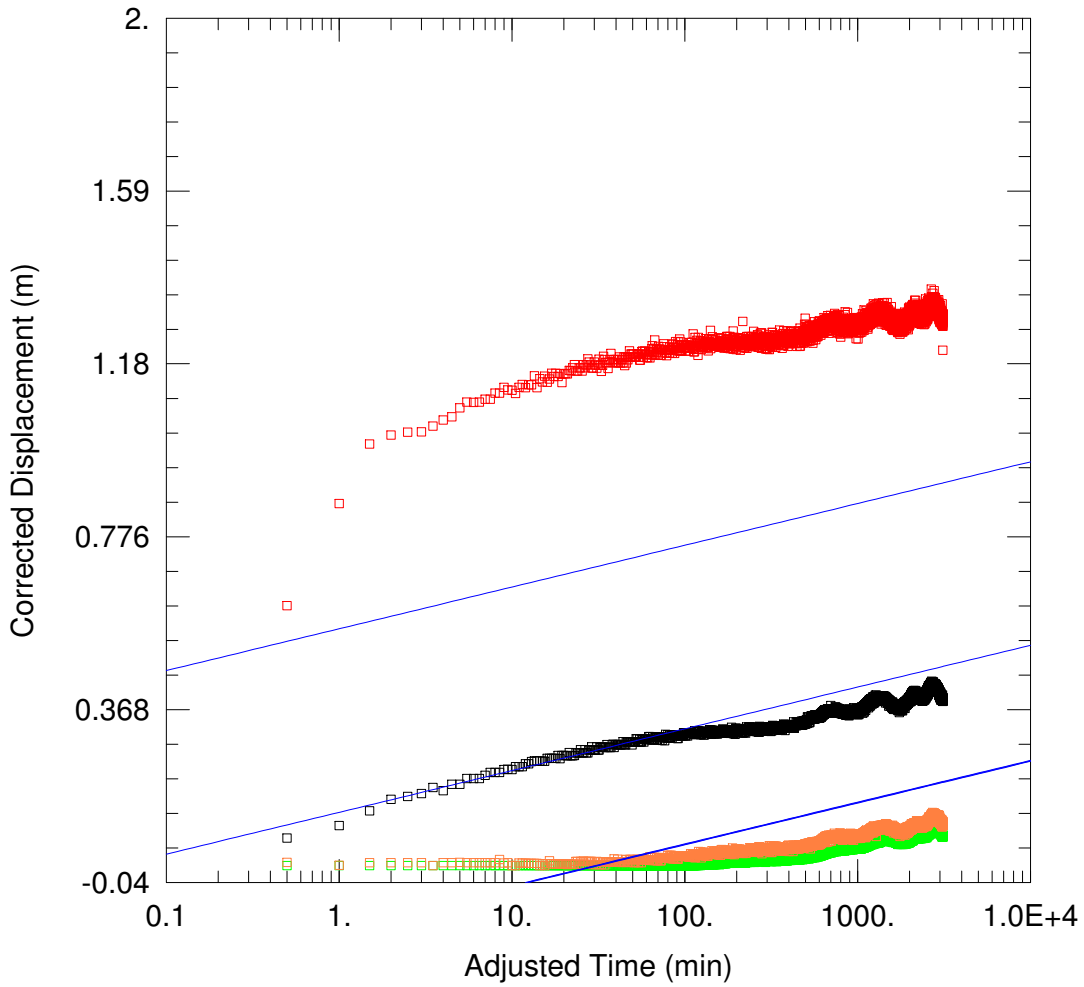
Observation Wells

Well Name	X (m)	Y (m)
MDPB0017	666392	7548457
MDPZ9204	666360.69	7548461
MDPZ7456A	665850.759	7547906.099
MDPZ7456B	665865.231	7547917.735
MDPZ7456C	665858.433	7547912.293

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 3523.8 m^2/day
S = 0.001669
Kz/Kr = 1.936E+4
b = 88. m



WELL TEST ANALYSIS

Data Set: C:\Users\EJBolton\Documents\Drafts etc\171\Task J\Test Pumping\MDPB0017_CJ_9204.aqt
Date: 03/17/22 Time: 10:03:29

PROJECT INFORMATION

Company: AQ2
Client: Roy Hill
Project: 171J
Location: Mulga East
Test Well: MDPB0017

AQUIFER DATA

Saturated Thickness: 88. m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0017	666392	7548457

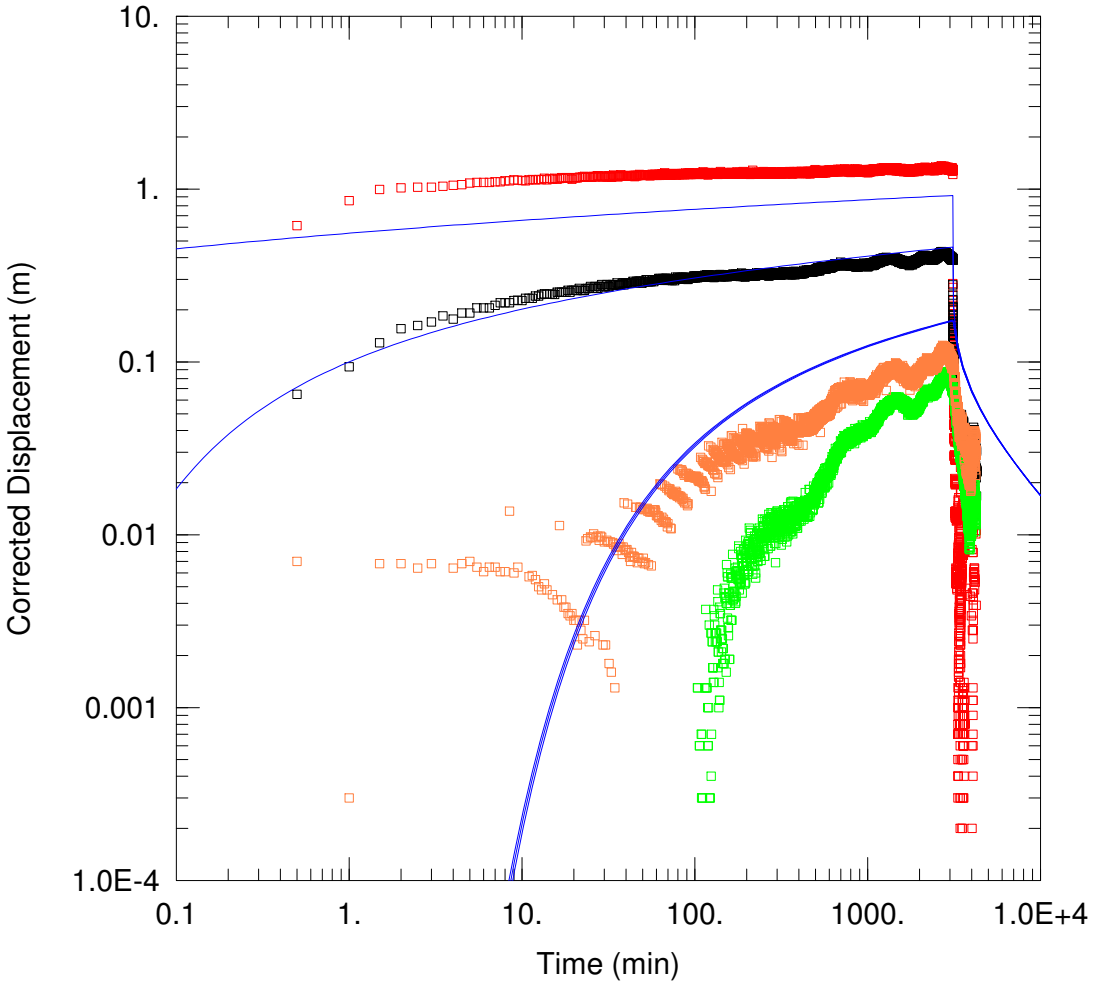
Observation Wells

Well Name	X (m)	Y (m)
MDPB0017	666392	7548457
MDPZ9204	666360.69	7548461
MDPZ7456A	665850.759	7547906.099
MDPZ7456B	665865.231	7547917.735
MDPZ7456C	665858.433	7547912.293

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 6425.7 m^2/day S = 0.0005383



WELL TEST ANALYSIS

Data Set: C:\...\MDPB0017_Theis_9204.aqt
Date: 03/17/22 Time: 10:25:06

PROJECT INFORMATION

Company: AQ2
Client: Roy Hill
Project: 171J
Location: Mulga East
Test Well: MDPB0017

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0017	666392	7548457

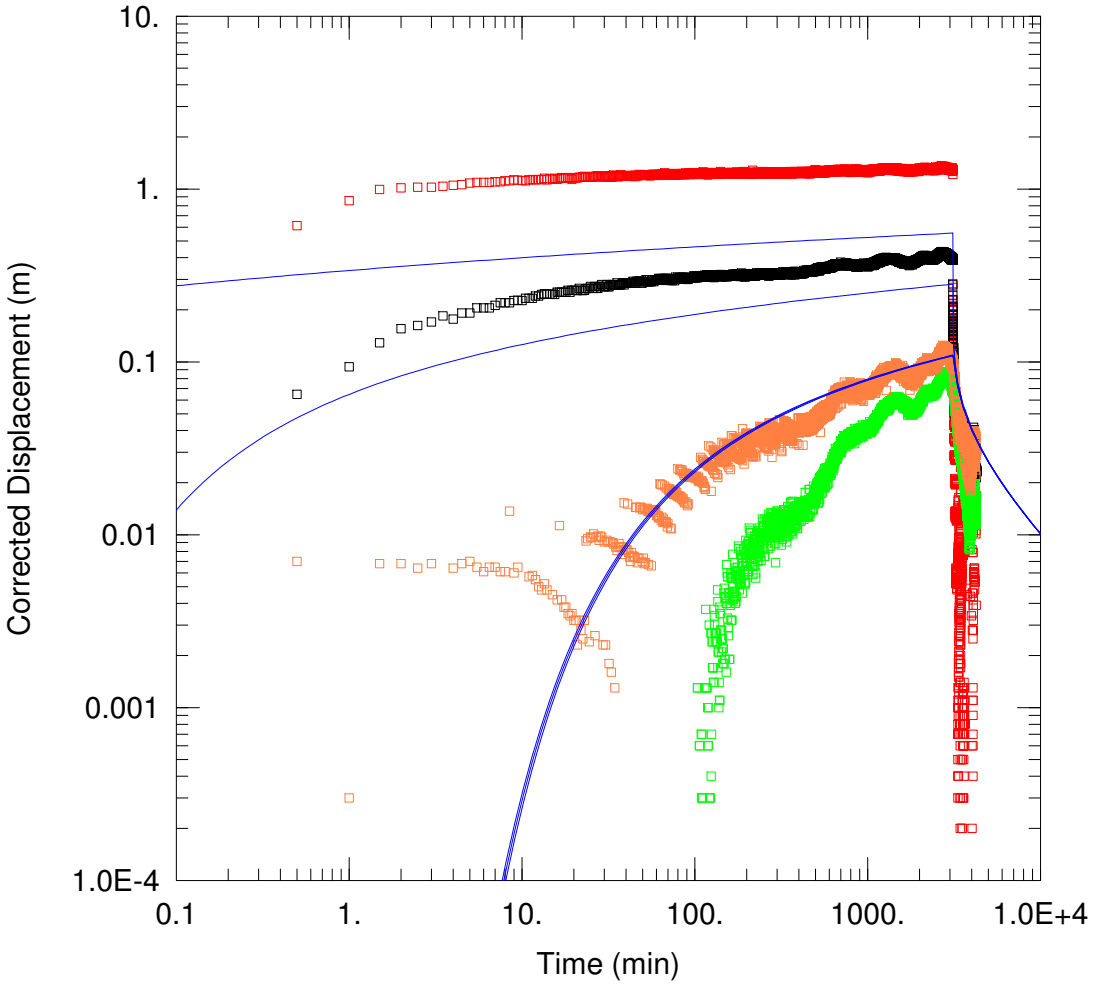
Observation Wells

Well Name	X (m)	Y (m)
MDPB0017	666392	7548457
MDPZ9204	666360.69	7548461
MDPZ7456A	665850.759	7547906.099
MDPZ7456B	665865.231	7547917.735
MDPZ7456C	665858.433	7547912.293

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 6085.7 m^2/day
S = 0.001113
Kz/Kr = 0.1
b = 88. m



WELL TEST ANALYSIS

Data Set: C:\...\MDPB0017_Theis_7456B.aqt
Date: 03/17/22 Time: 10:19:28

PROJECT INFORMATION

Company: AQ2
Client: Roy Hill
Project: 171J
Location: Mulga East
Test Well: MDPB0017

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0017	666392	7548457

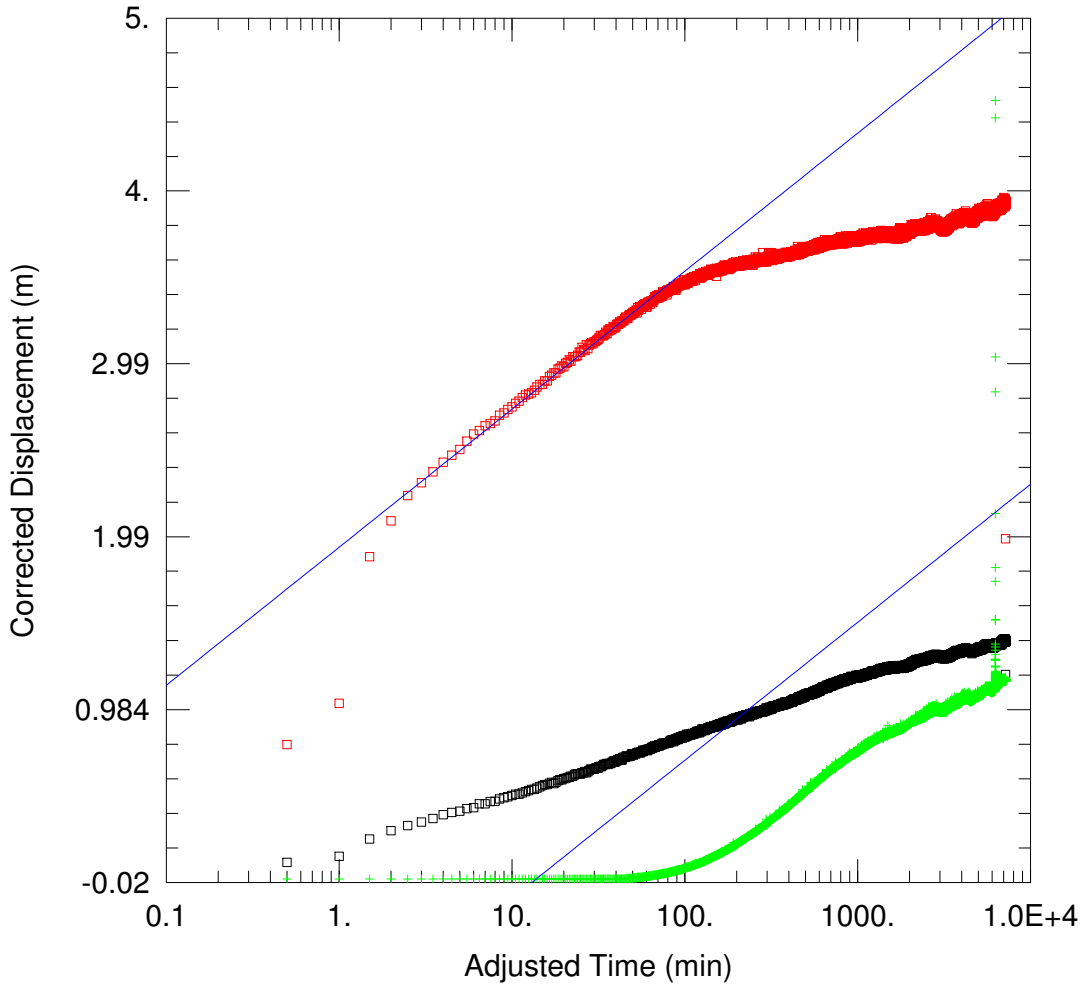
Observation Wells

Well Name	X (m)	Y (m)
MDPB0017	666392	7548457
MDPZ9204	666360.69	7548461
MDPZ7456A	665850.759	7547906.099
MDPZ7456B	665865.231	7547917.735
MDPZ7456C	665858.433	7547912.293

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 1.015E+4 m^2/day
S = 0.001533
Kz/Kr = 0.1
b = 88. m



WELL TEST ANALYSIS

Data Set: C:\Users\EJBolton\Documents\Drafts etc\171\Task J\Test Pumping\MDPB0018_CJ_early.aqt
Date: 03/17/22 Time: 12:19:49

PROJECT INFORMATION

Company: AQ2
Client: Roy Hill
Project: 171J
Location: Mulga East
Test Well: MDPB0018
Test Date: 04/10/2021

AQUIFER DATA

Saturated Thickness: 73. m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0018	669188	7549122

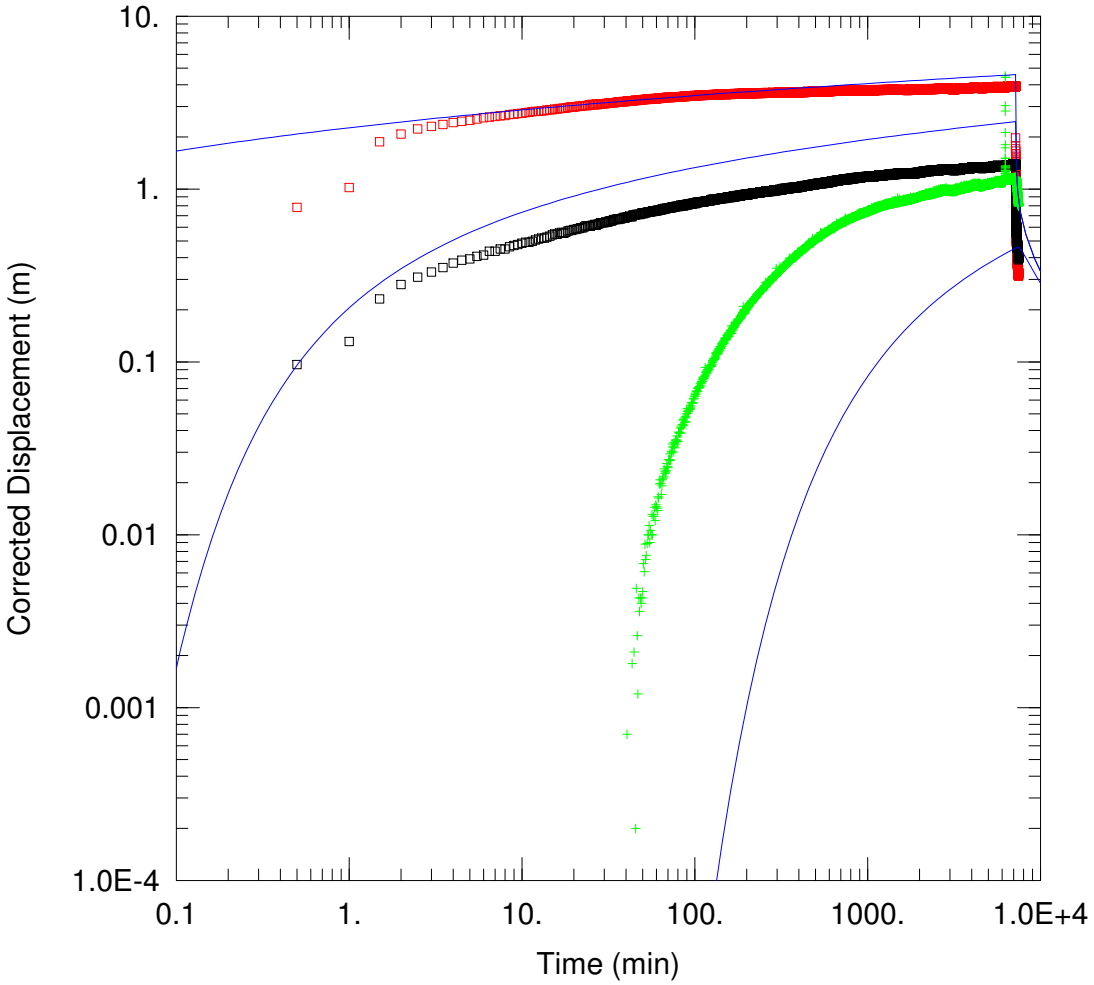
Observation Wells

Well Name	X (m)	Y (m)
MDPB0018	669188	7549122
MDPZ9206	669177.433	7549127.317
MDPZ7933	668714.628	7549418.105

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 750.5 m^2/day S = 0.1156



WELL TEST ANALYSIS

Data Set: F:\171\2.TECH\PFS Test Pumping\MDPB0018\Late time not used\MDPB0018_Theis.aqt
Date: 03/17/22 Time: 12:35:13

PROJECT INFORMATION

Company: AQ2
Client: Roy Hill
Project: 171J
Location: Mulga East
Test Well: MDPB0018
Test Date: 04/10/2021

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0018	669188	7549122

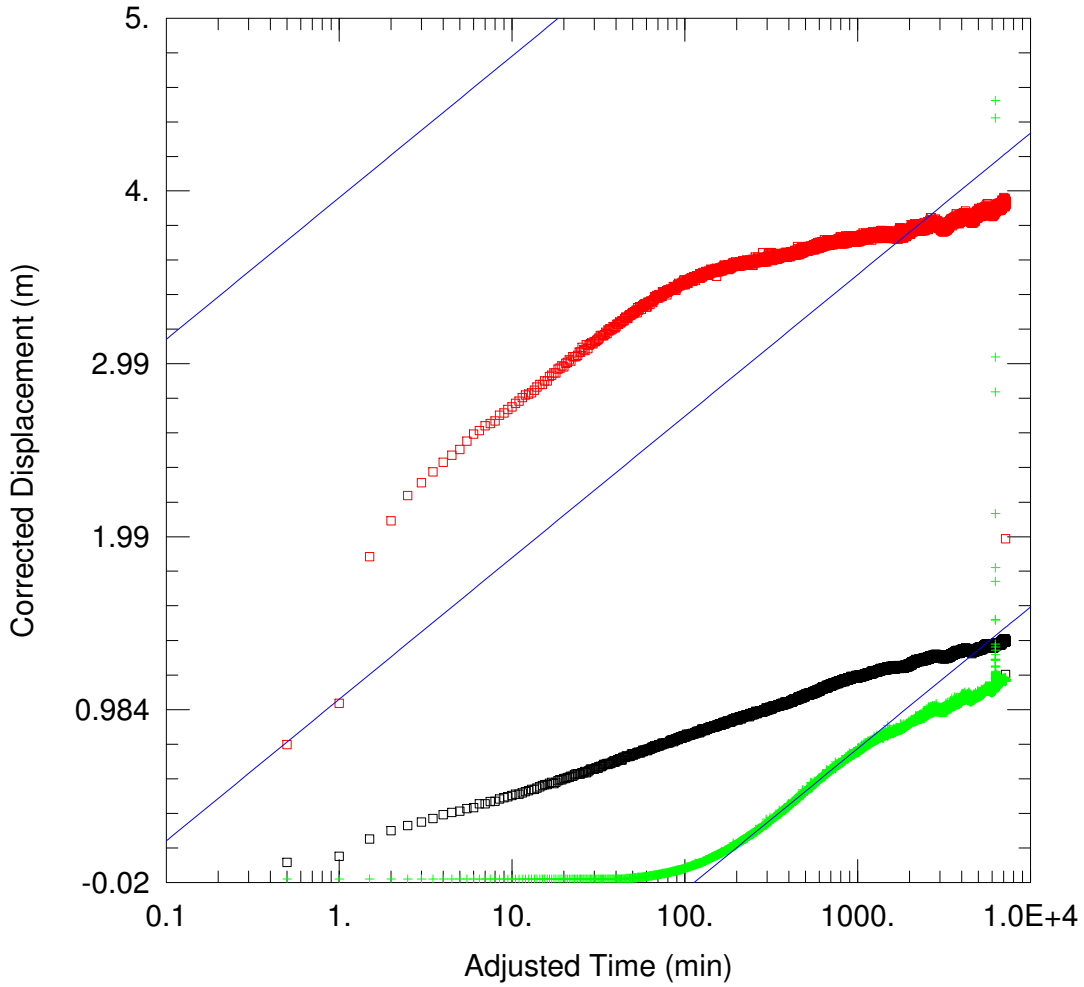
Observation Wells

Well Name	X (m)	Y (m)
MDPB0018	669188	7549122
MDPZ9206	669177.4337	549127.317
MDPZ7933	668714.6287	549418.105

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 995.6 m^2/day
S = 0.007047
Kz/Kr = 0.1
b = 73. m



WELL TEST ANALYSIS

Data Set: C:\Users\EJBolton\Documents\Drafts etc\171\Task J\Test Pumping\MDPB0018_CJ_7933.aqt
Date: 03/17/22 Time: 12:16:24

PROJECT INFORMATION

Company: AQ2
Client: Roy Hill
Project: 171J
Location: Mulga East
Test Well: MDPB0018
Test Date: 04/10/2021

AQUIFER DATA

Saturated Thickness: 73. m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0018	669188	7549122

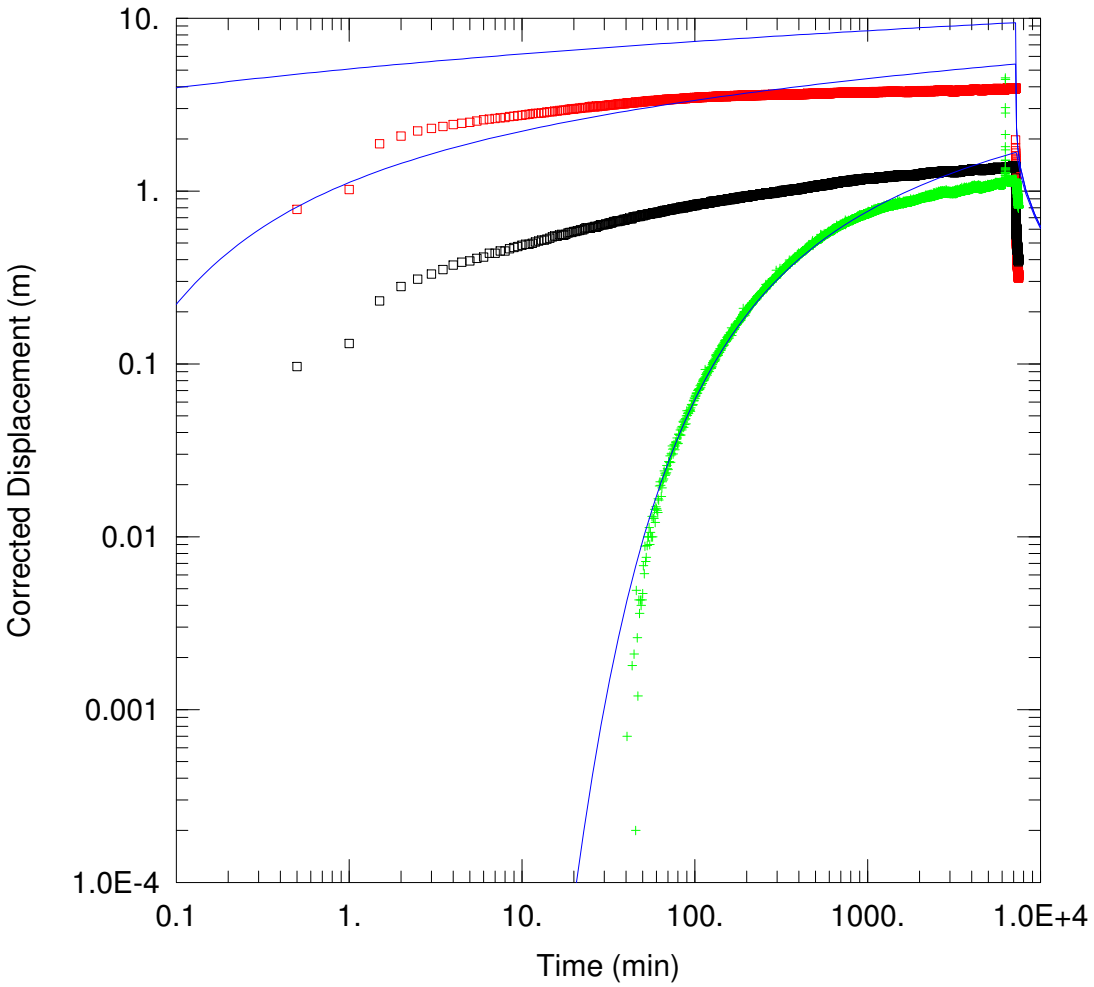
Observation Wells

Well Name	X (m)	Y (m)
MDPB0018	669188	7549122
MDPZ9206	669177.433	7549127.317
MDPZ7933	668714.628	7549418.105

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 731.7 m^2/day S = 0.0004392



WELL TEST ANALYSIS

Data Set: F:\...\MDPB0018_Theis_9733.aqt
Date: 03/17/22 Time: 12:42:39

PROJECT INFORMATION

Company: AQ2
Client: Roy Hill
Project: 171J
Location: Mulga East
Test Well: MDPB0018
Test Date: 04/10/2021

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0018	669188	7549122

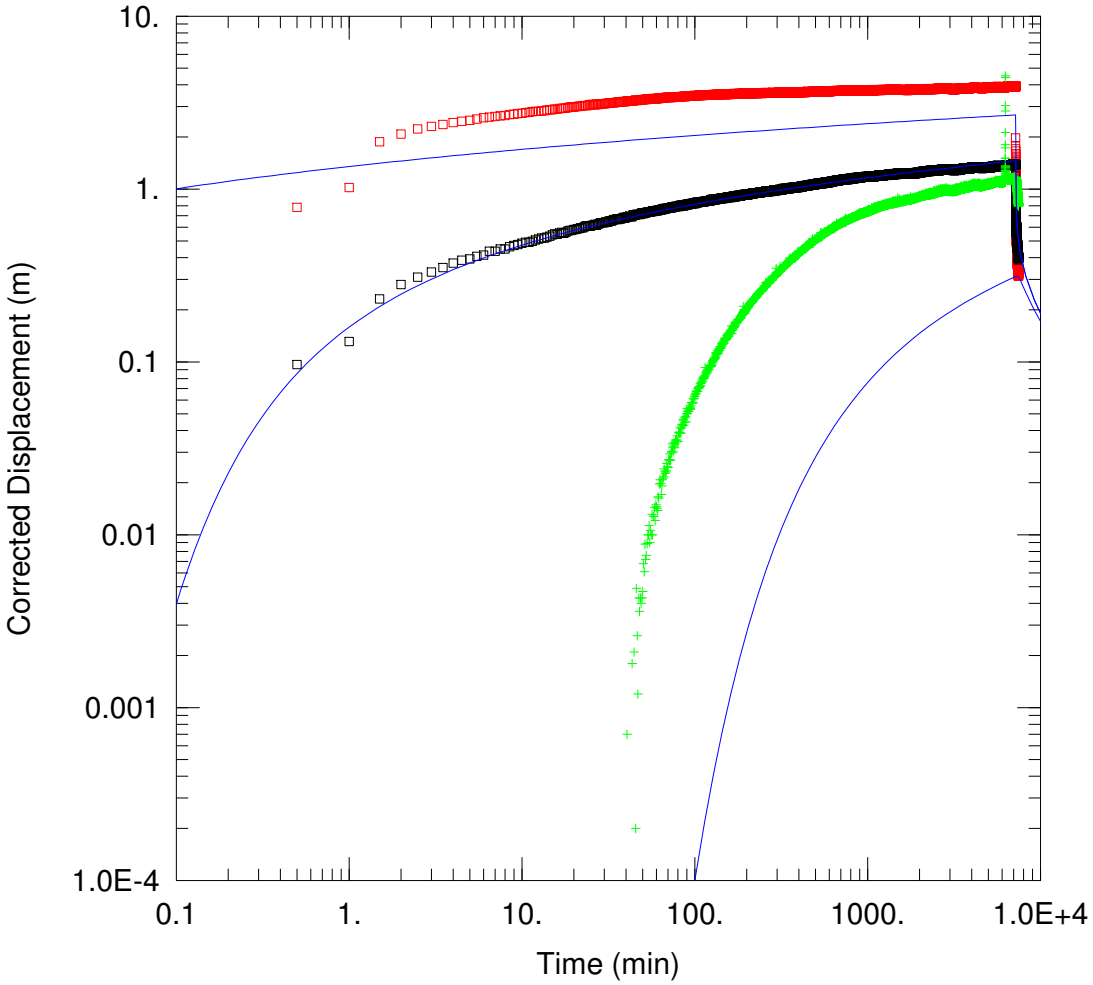
Observation Wells

Well Name	X (m)	Y (m)
MDPB0018	669188	7549122
MDPZ9206	669177.433	7549127.317
MDPZ7933	668714.628	7549418.105

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 534.6 m^2/day
S = 0.0006402
Kz/Kr = 0.1
b = 73. m



WELL TEST ANALYSIS

Data Set: F:\171\2.TECH\PFS Test Pumping\MDPB0018\MDPB0018.aqt
Date: 01/07/22 Time: 14:13:07

PROJECT INFORMATION

Company: AQ2
Client: Roy Hill
Project: 171J
Location: Mulga East
Test Well: MDPB0018
Test Date: 04/10/2021

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0018	669188	7549122

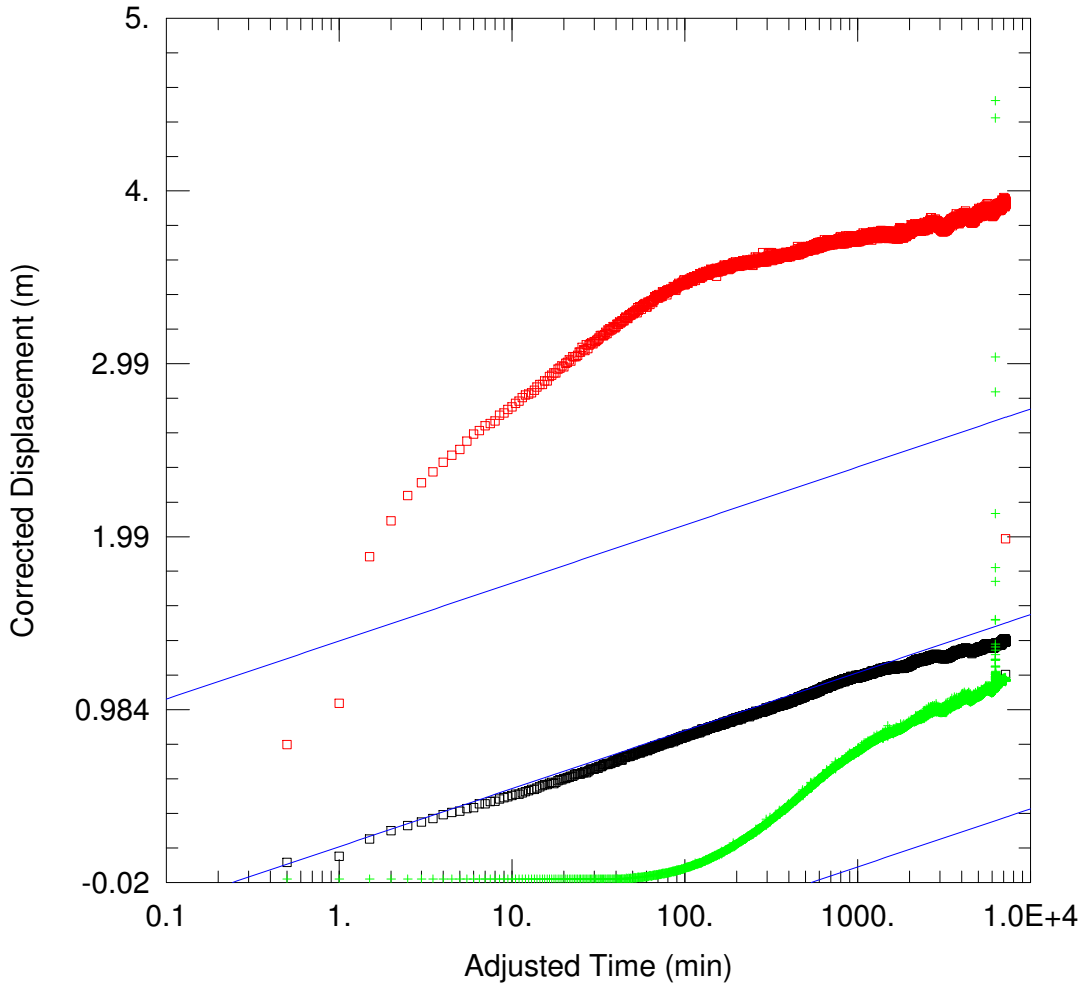
Observation Wells

Well Name	X (m)	Y (m)
MDPB0018	669188	7549122
MDPZ9206	669177.433	7549127.317
MDPZ7933	668714.628	7549418.105

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 1740.8 m^2/day
S = 0.008491
Kz/Kr = 0.1
b = 73. m



WELL TEST ANALYSIS

Data Set: C:\Users\EJBolton\Documents\Drafts etc\171\Task J\Test Pumping\MDPB0018_CJ_9206.aqt
Date: 03/17/22 Time: 12:18:07

PROJECT INFORMATION

Company: AQ2
Client: Roy Hill
Project: 171J
Location: Mulga East
Test Well: MDPB0018
Test Date: 04/10/2021

AQUIFER DATA

Saturated Thickness: 73. m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0018	669188	7549122

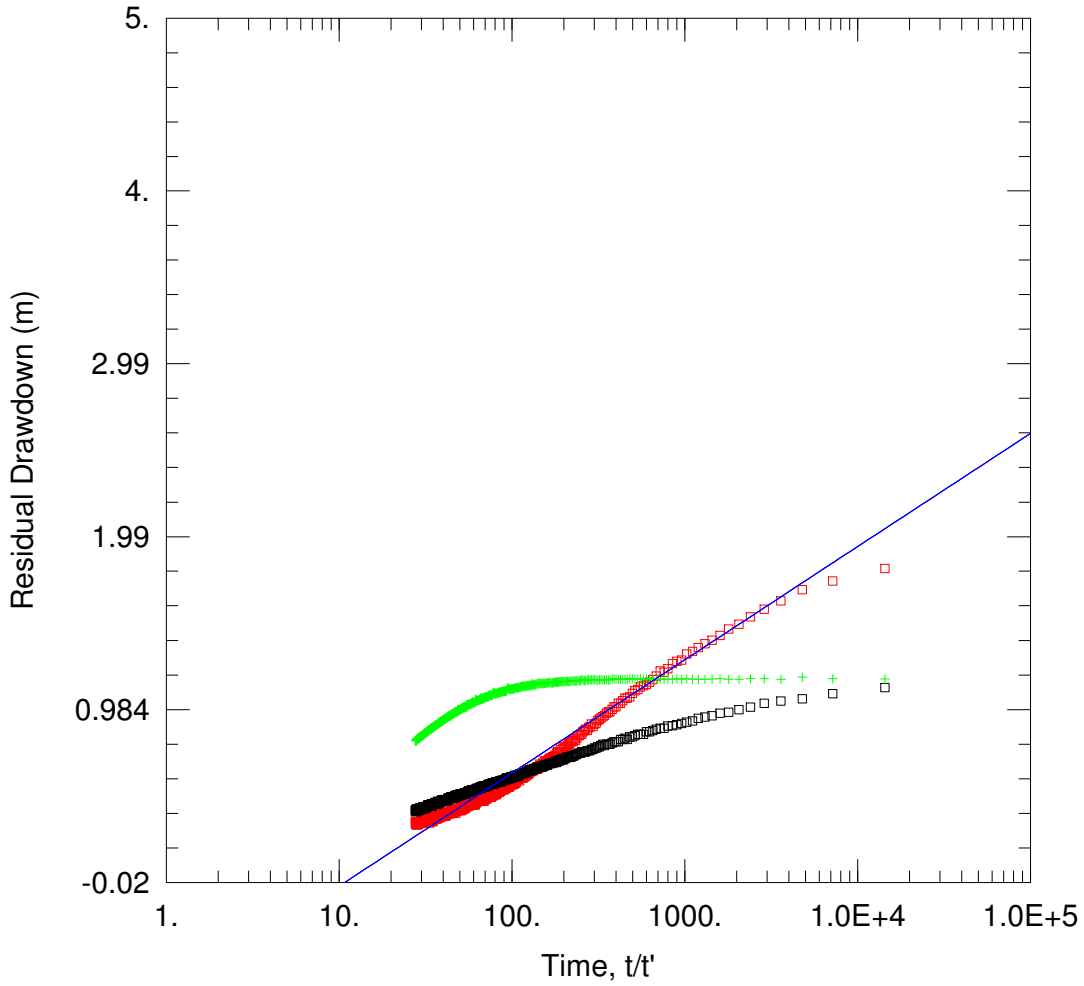
Observation Wells

Well Name	X (m)	Y (m)
MDPB0018	669188	7549122
MDPZ9206	669177.433	7549127.317
MDPZ7933	668714.628	7549418.105

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 1785.1 m^2/day S = 0.005534



WELL TEST ANALYSIS

Data Set: C:\Users\EJBolton\Documents\Drafts etc\171\Task J\Test Pumping\MDPB0018_rec.aqt
Date: 03/17/22 Time: 12:20:24

PROJECT INFORMATION

Company: AQ2
Client: Roy Hill
Project: 171J
Location: Mulga East
Test Well: MDPB0018
Test Date: 04/10/2021

AQUIFER DATA

Saturated Thickness: 73. m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0018	669188	7549122

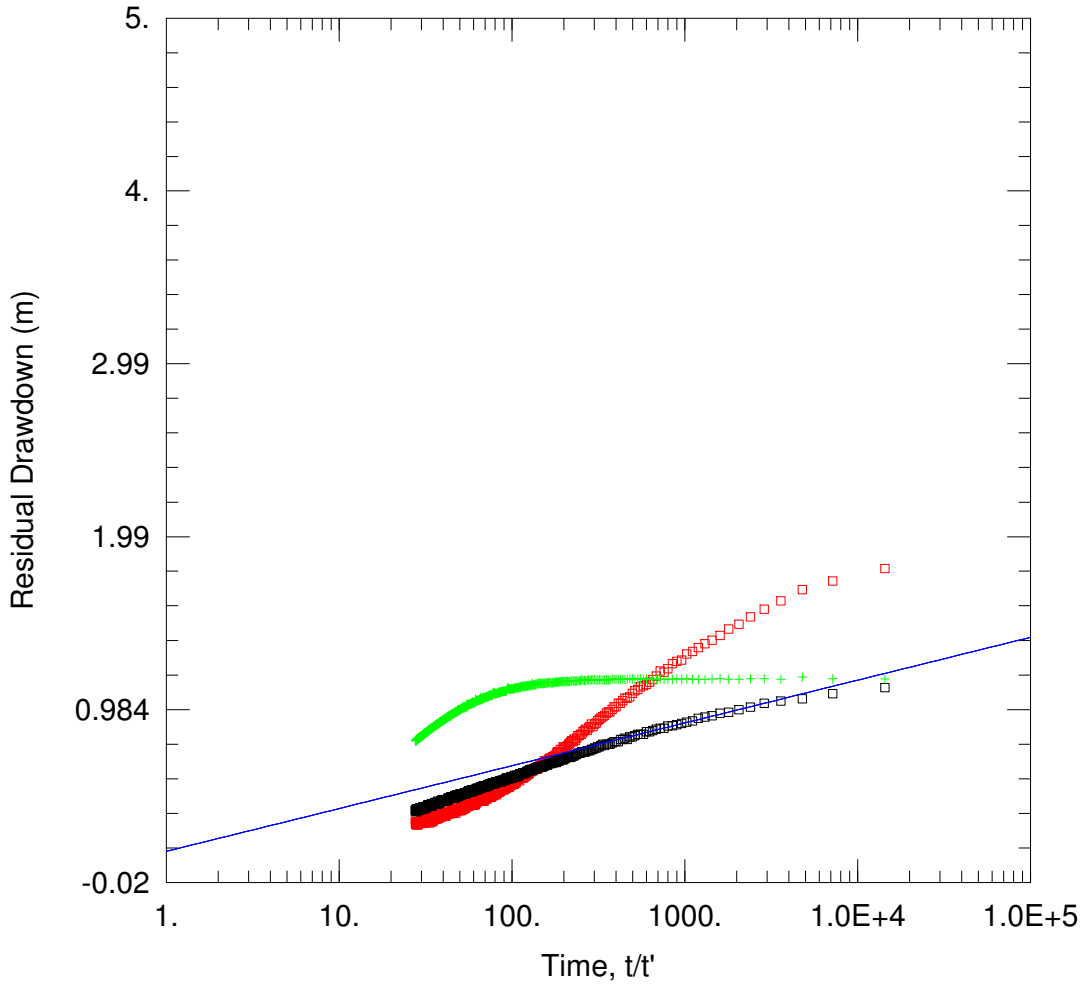
Observation Wells

Well Name	X (m)	Y (m)
MDPB0018	669188	7549122
MDPZ9206	669177.433	7549127.317
MDPZ7933	668714.628	7549418.105

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 915.3 m^2/day S/S' = 11.58



WELL TEST ANALYSIS

Data Set: C:\Users\EJBolton\Documents\Drafts etc\171\Task J\Test Pumping\MDPB0018_rec_9206.aqt
Date: 03/17/22 Time: 12:21:35

PROJECT INFORMATION

Company: AQ2
Client: Roy Hill
Project: 171J
Location: Mulga East
Test Well: MDPB0018
Test Date: 04/10/2021

AQUIFER DATA

Saturated Thickness: 73. m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0018	669188	7549122

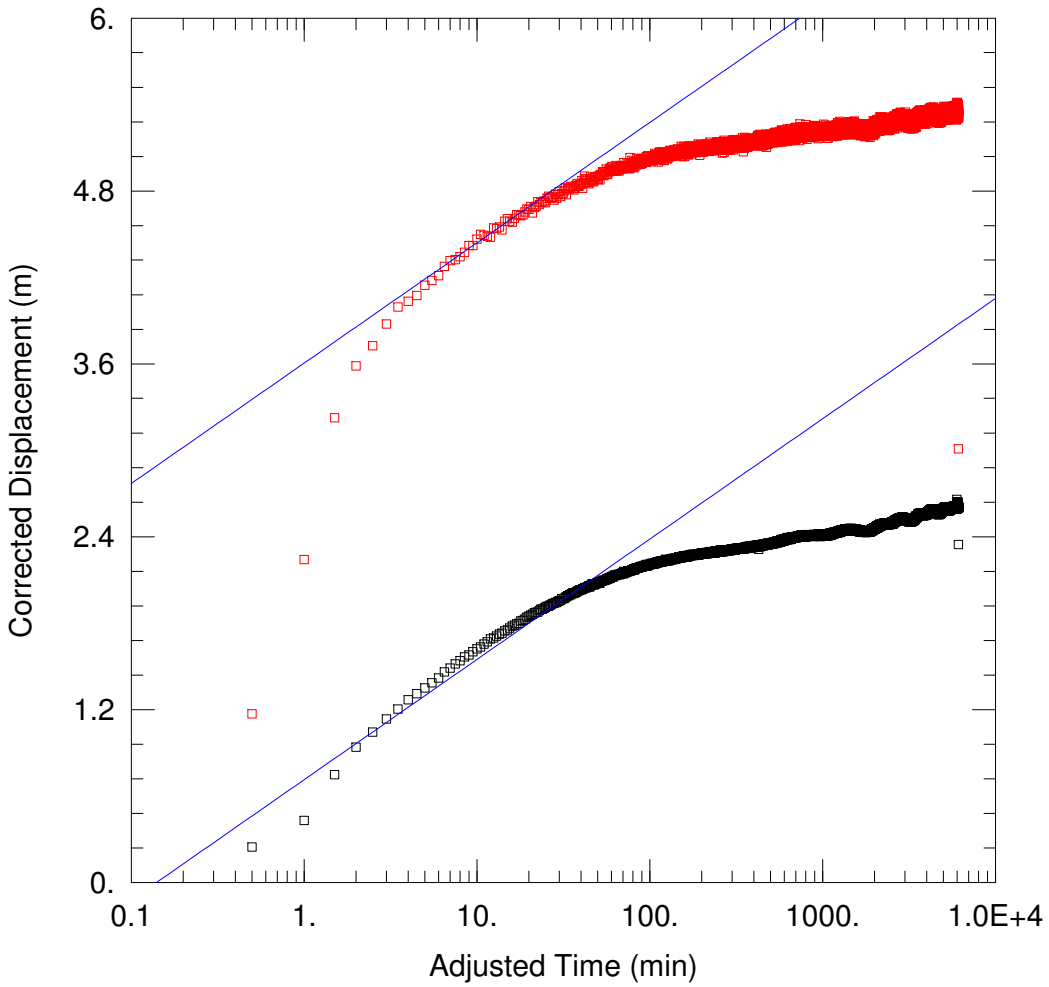
Observation Wells

Well Name	X (m)	Y (m)
MDPB0018	669188	7549122
MDPZ9206	669177.433	7549127.317
MDPZ7933	668714.628	7549418.105

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 2420.3 m^2/day S/S' = 0.2268



WELL TEST ANALYSIS

Data Set: C:\Users\EJBolton\Documents\Drafts etc\171\Task J\Test Pumping\MDPB0019_CJ_early.aqt
Date: 03/17/22 Time: 12:51:43

PROJECT INFORMATION

Company: AQ2
Client: Roy Hill
Project: 171J
Location: Mulga East
Test Well: MDPB0019
Test Date: 04/10/2021

AQUIFER DATA

Saturated Thickness: 53. m Anisotropy Ratio (Kz/Kr): 7022.5

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0019	661999	7552117

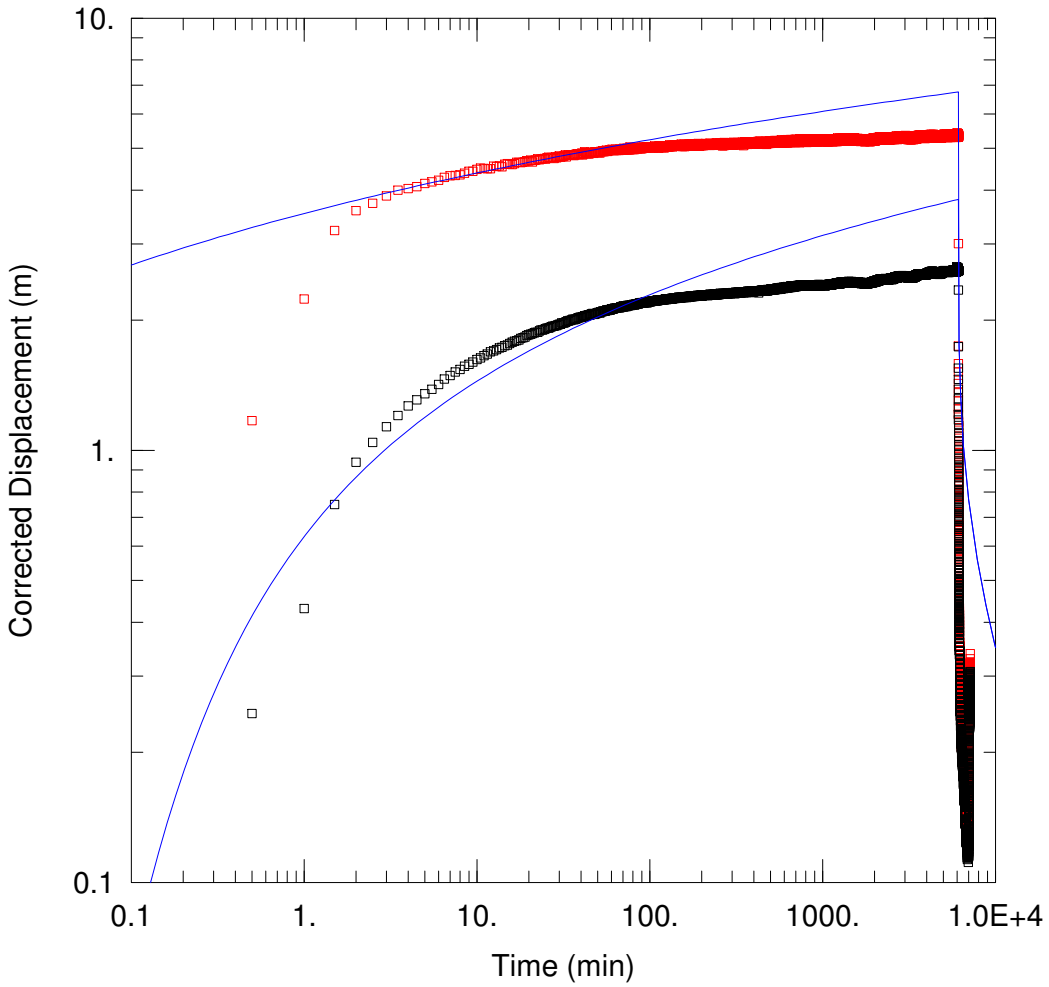
Observation Wells

Well Name	X (m)	Y (m)
MDPB0019	661999	7552117
MDPZ9207	661995	7552127

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 720.2 m^2/day S = 0.001358



WELL TEST ANALYSIS

Data Set: C:\Users\EJBolton\Documents\Drafts etc\171\Task J\Test Pumping\MDPB0019_Theis.aqt
Date: 03/17/22 Time: 12:58:07

PROJECT INFORMATION

Company: AQ2
Client: Roy Hill
Project: 171J
Location: Mulga East
Test Well: MDPB0019
Test Date: 04/10/2021

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0019	661999	7552117

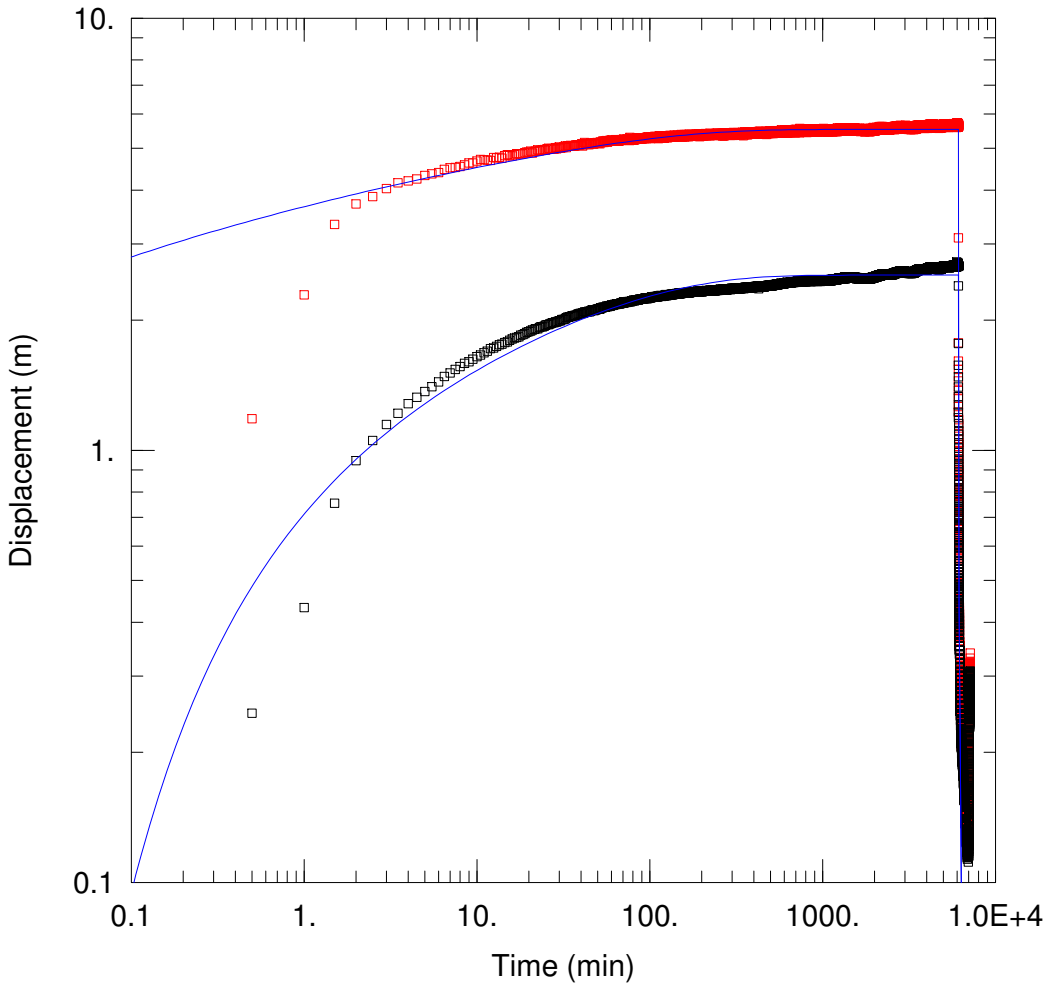
Observation Wells

Well Name	X (m)	Y (m)
MDPB0019	661999	7552117
MDPZ9207	661995	7552127

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 708. m^2/day
S = 0.001921
Kz/Kr = 7022.5
b = 53. m



WELL TEST ANALYSIS

Data Set: C:\Users\EJBolton\Documents\Drafts etc\171\Task J\Test Pumping\MDPB0019_Leaky.aqt
Date: 03/17/22 Time: 12:53:51

PROJECT INFORMATION

Company: AQ2
Client: Roy Hill
Project: 171J
Location: Mulga East
Test Well: MDPB0019
Test Date: 04/10/2021

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0019	661999	7552117

Observation Wells

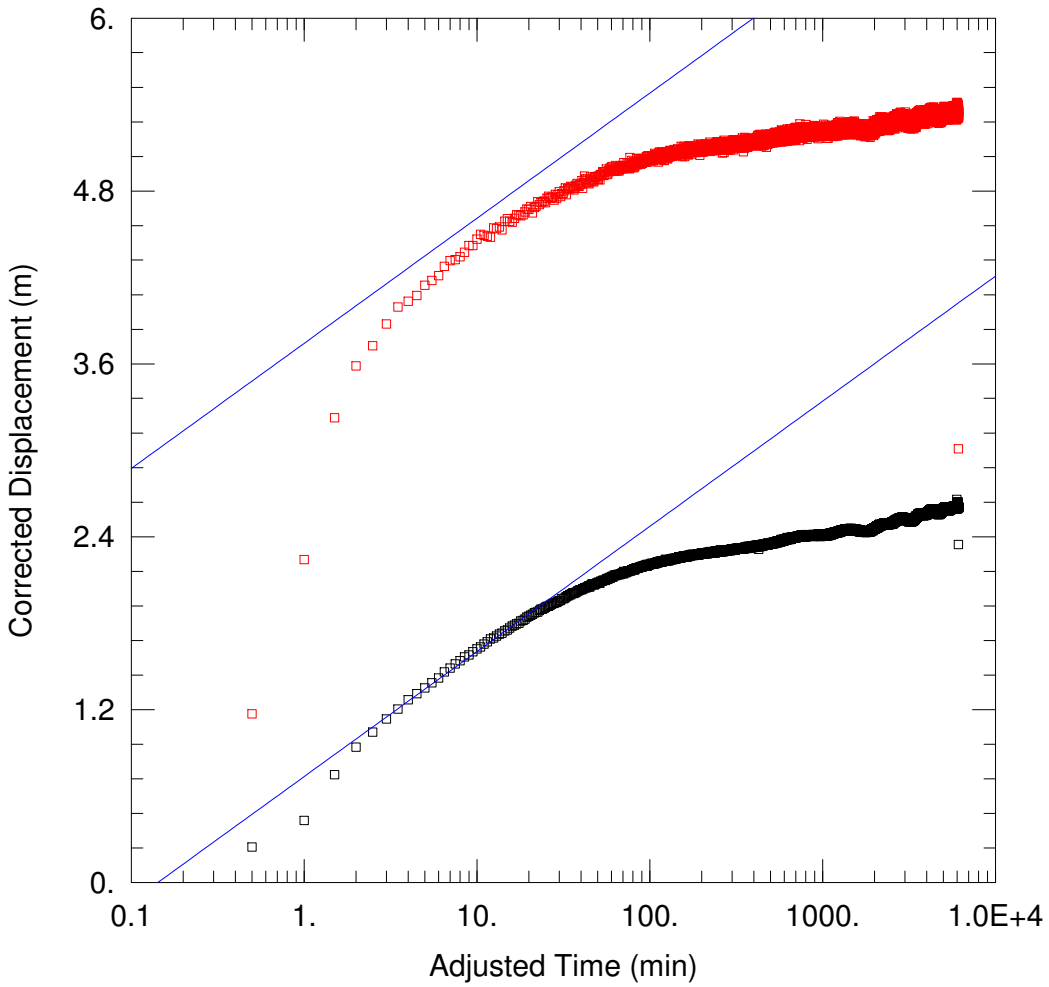
Well Name	X (m)	Y (m)
MDPB0019	661999	7552117
MDPZ9207	661995	7552127

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush-Jacob

T = 698.1 m^2/day
1/B = 0.003497 m^{-1}
b = 53. m

S = 0.001531
Kz/Kr = 7022.5



WELL TEST ANALYSIS

Data Set: C:\Users\EJBolton\Documents\Drafts etc\171\Task J\Test Pumping\MDPB0019_CJ_9207.aqt
Date: 03/17/22 Time: 12:52:46

PROJECT INFORMATION

Company: AQ2
Client: Roy Hill
Project: 171J
Location: Mulga East
Test Well: MDPB0019
Test Date: 04/10/2021

AQUIFER DATA

Saturated Thickness: 53. m Anisotropy Ratio (Kz/Kr): 7022.5

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0019	661999	7552117

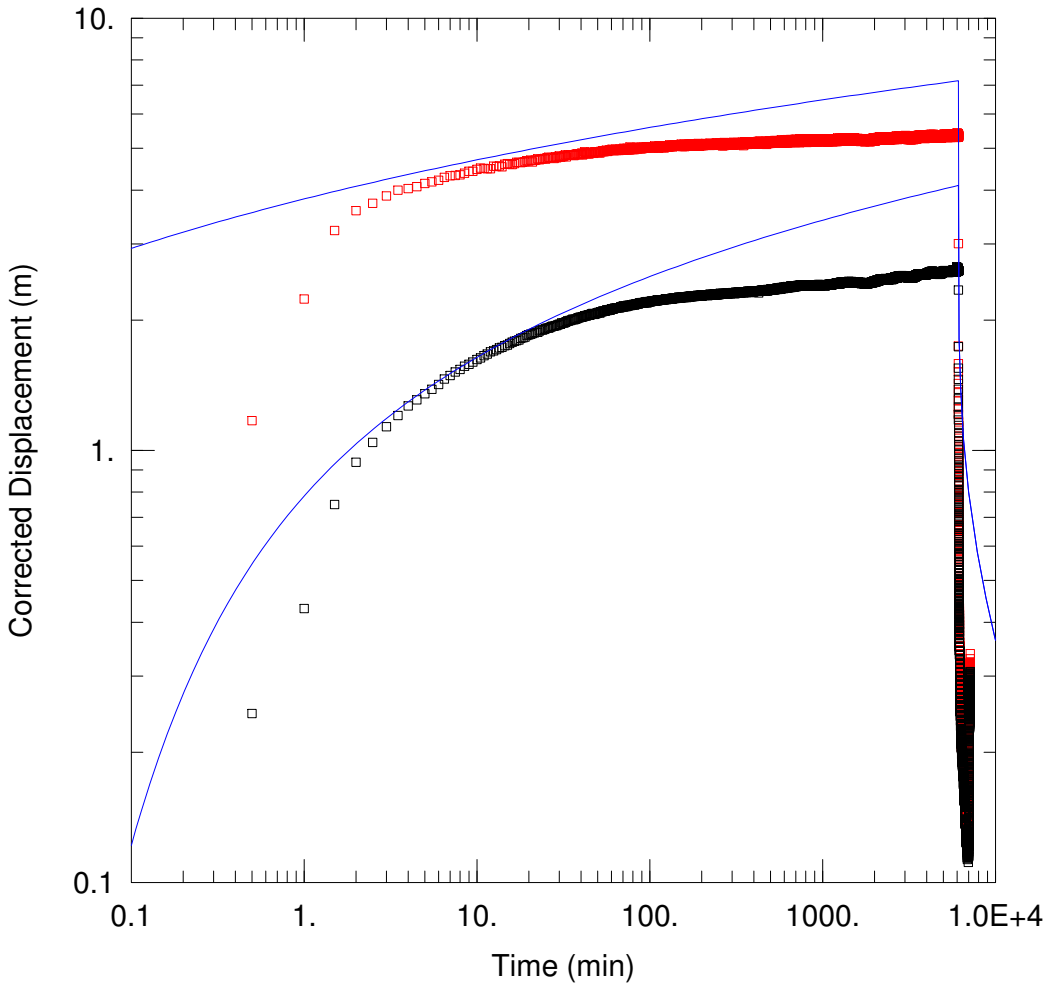
Observation Wells

Well Name	X (m)	Y (m)
MDPB0019	661999	7552117
MDPZ9207	661995	7552127

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 692.6 m^2/day S = 0.001329



WELL TEST ANALYSIS

Data Set: C:\...\MDPB0019_Theis_9207.aqt
Date: 03/17/22 Time: 13:00:09

PROJECT INFORMATION

Company: AQ2
Client: Roy Hill
Project: 171J
Location: Mulga East
Test Well: MDPB0019
Test Date: 04/10/2021

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0019	661999	7552117

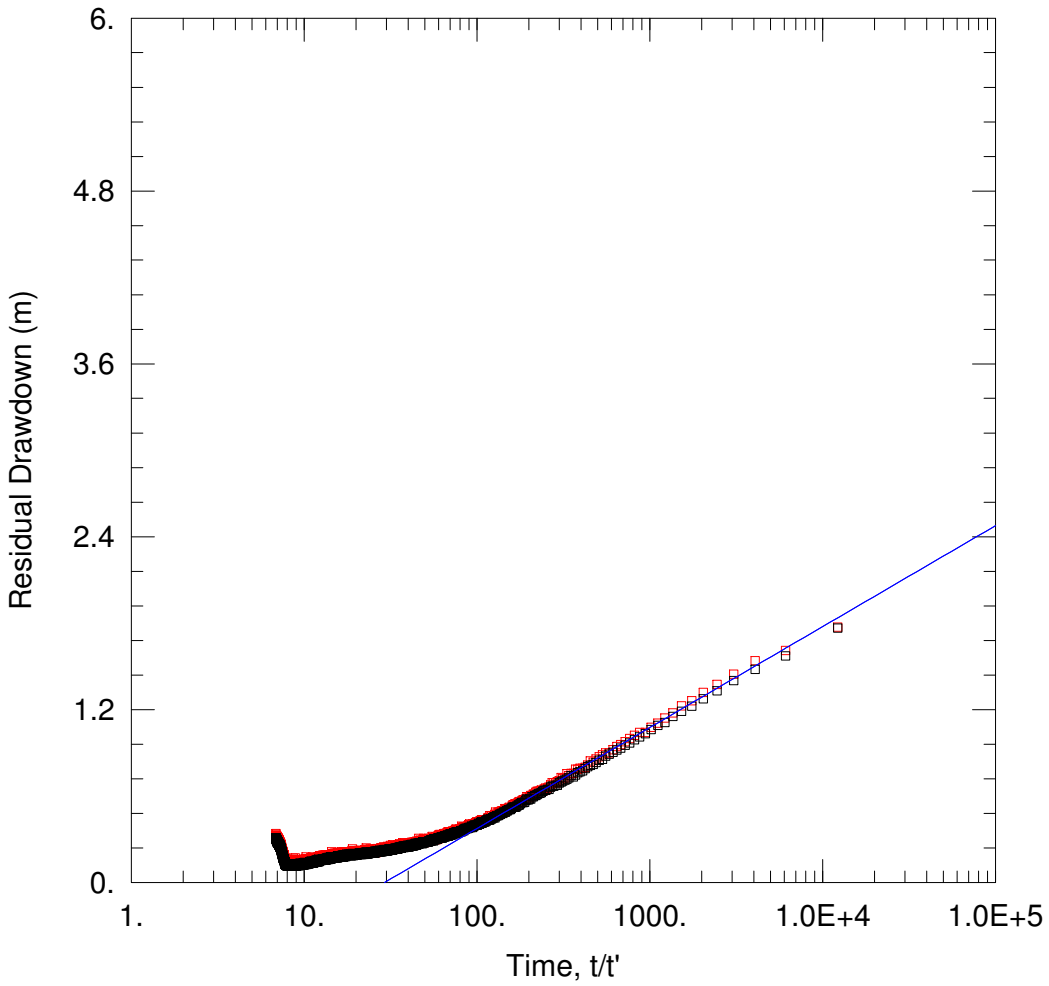
Observation Wells

Well Name	X (m)	Y (m)
MDPB0019	661999	7552117
MDPZ9207	661995	7552127

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 680.4 m^2/day
S = 0.001285
Kz/Kr = 7022.5
b = 53. m



WELL TEST ANALYSIS

Data Set: C:\Users\EJBolton\Documents\Drafts etc\171\Task J\Test Pumping\MDPB0019_rec.aqt
Date: 03/17/22 Time: 12:55:11

PROJECT INFORMATION

Company: AQ2
Client: Roy Hill
Project: 171J
Location: Mulga East
Test Well: MDPB0019
Test Date: 04/10/2021

AQUIFER DATA

Saturated Thickness: 53. m Anisotropy Ratio (Kz/Kr): 7022.5

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0019	661999	7552117

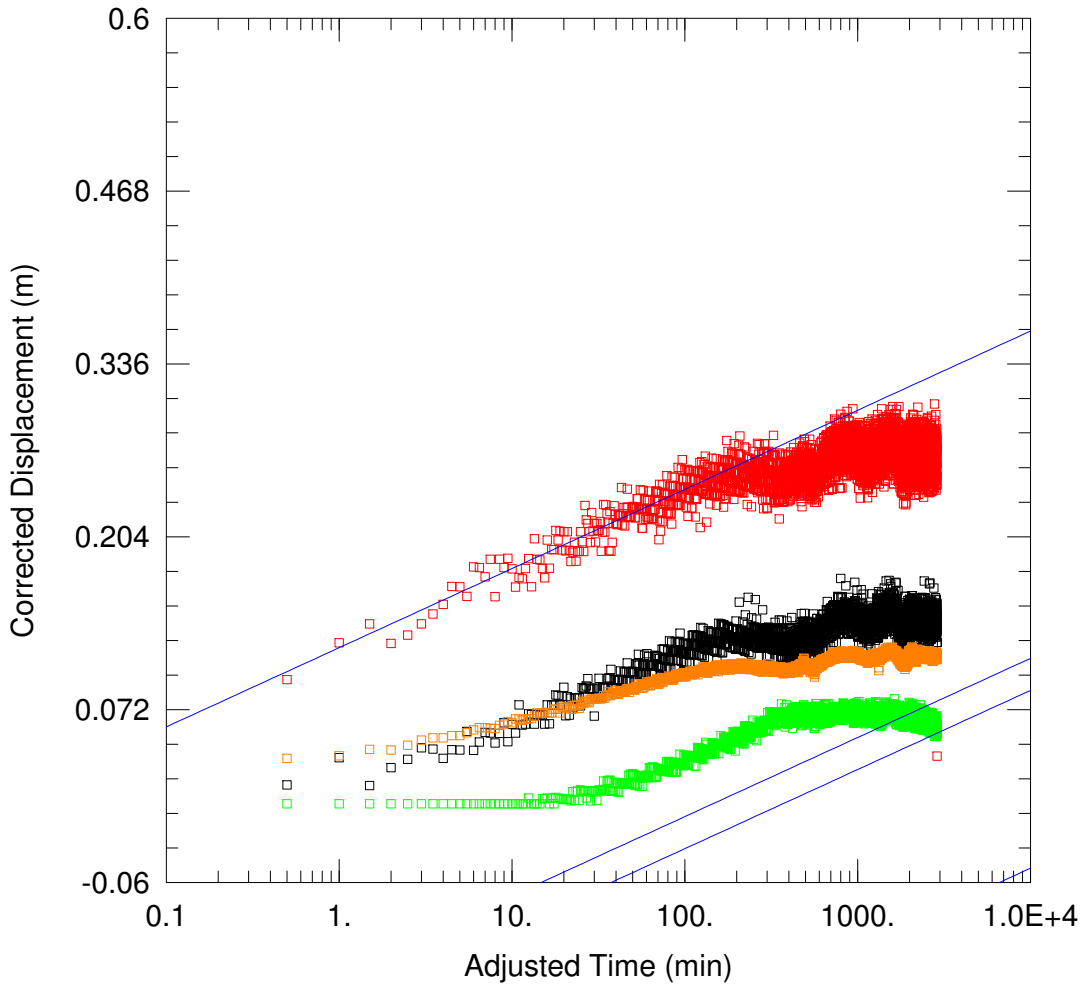
Observation Wells

Well Name	X (m)	Y (m)
MDPB0019	661999	7552117
MDPZ9207	661995	7552127

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 858.5 m^2/day S/S' = 29.26



WELL TEST ANALYSIS

Data Set: C:\Users\EJBolton\Documents\Drafts etc\171\Task J\Test Pumping\MDPB0020_CJ_early.aqt
Date: 03/17/22 Time: 13:10:11

PROJECT INFORMATION

Company: AQ2
Client: Roy Hill
Project: 171J
Location: Malay Well
Test Well: MDPB0020
Test Date: 10/12/2019

AQUIFER DATA

Saturated Thickness: 42. m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0020	654423	7546694

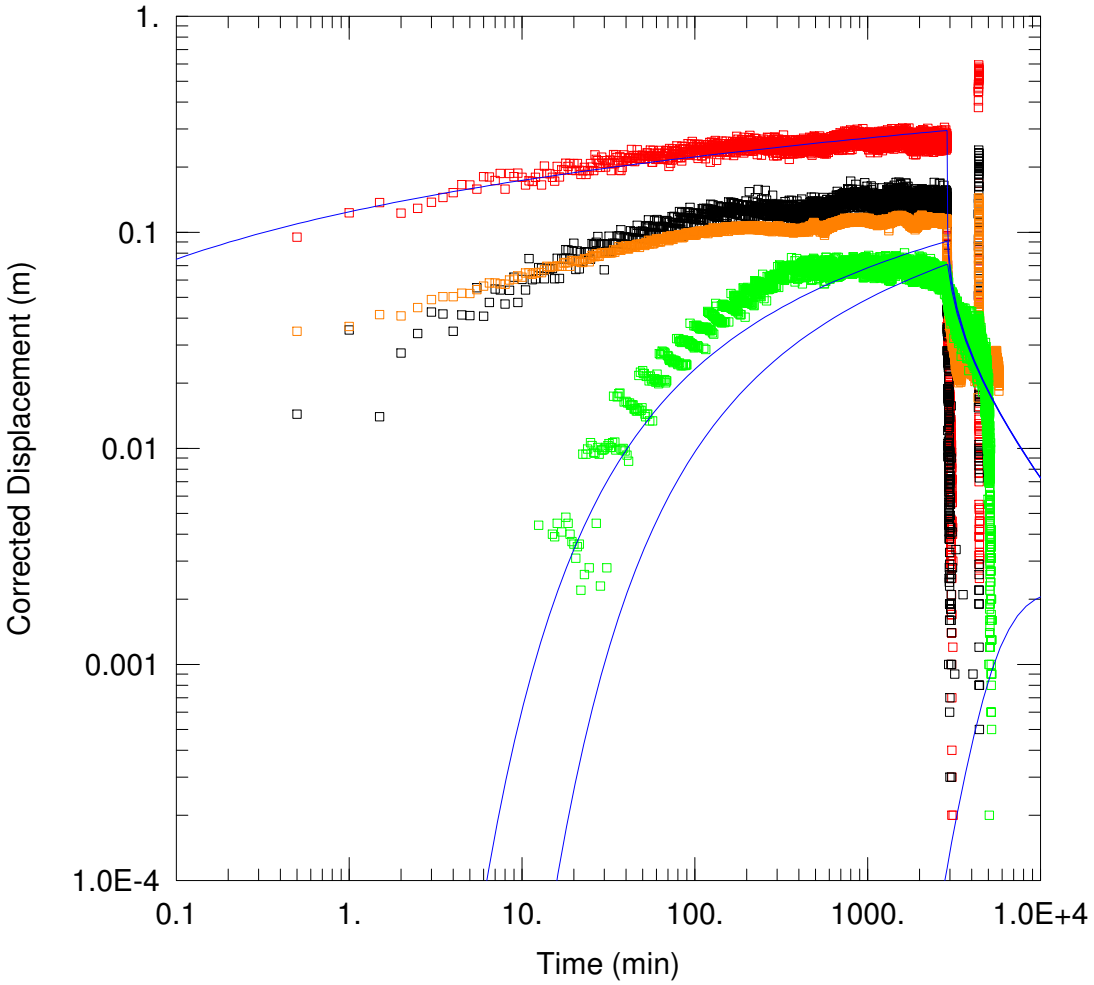
Observation Wells

Well Name	X (m)	Y (m)
MDPB0020	654423	7546694
MDPZ9212D	654400	7546690
MDPZ9212S	654386	7546690
MDPZ5355	654392	7546201

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 5238.1 m^2/day S = 2.178



WELL TEST ANALYSIS

Data Set: C:\Users\EJBolton\Documents\Drafts etc\171\Task J\Test Pumping\MDPB0020_Theis.aqt
Date: 03/17/22 Time: 13:32:33

PROJECT INFORMATION

Company: AQ2
Client: Roy Hill
Project: 171J
Location: Malay Well
Test Well: MDPB0020
Test Date: 10/12/2019

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0020	654423	7546694

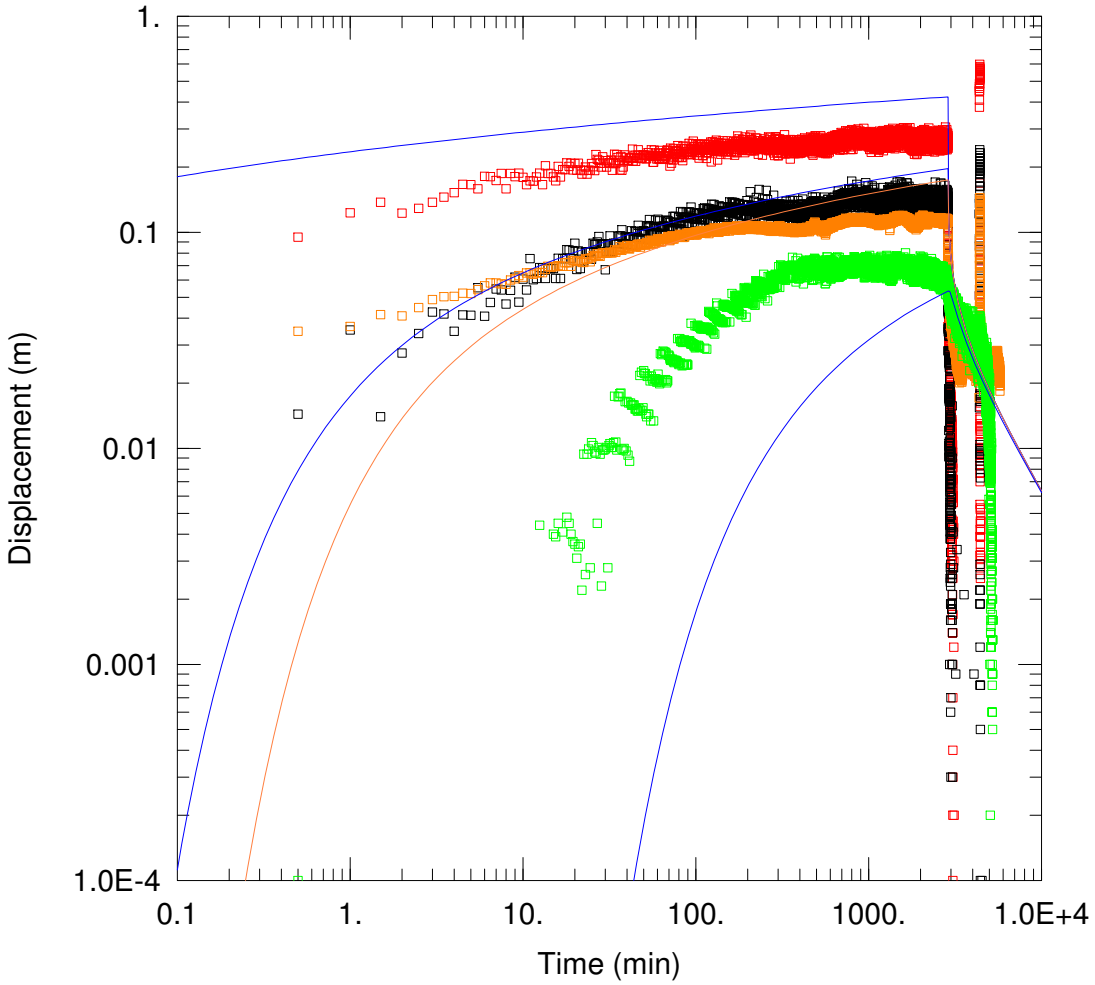
Observation Wells

Well Name	X (m)	Y (m)
MDPB0020	654423	7546694
MDPZ9212D	654400	7546690
MDPZ9212S	654386	7546690
MDPZ5355	654392	7546201

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 6387.9 m^2/day
S = 0.7809
Kz/Kr = 0.1
b = 42. m



WELL TEST ANALYSIS

Data Set: C:\...\MDPB0020_Leaky_9212D.aqt
Date: 03/17/22 Time: 13:23:16

PROJECT INFORMATION

Company: AQ2
Client: Roy Hill
Project: 171J
Location: Malay Well
Test Well: MDPB0020
Test Date: 10/12/2019

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0020	654423	7546694

Observation Wells

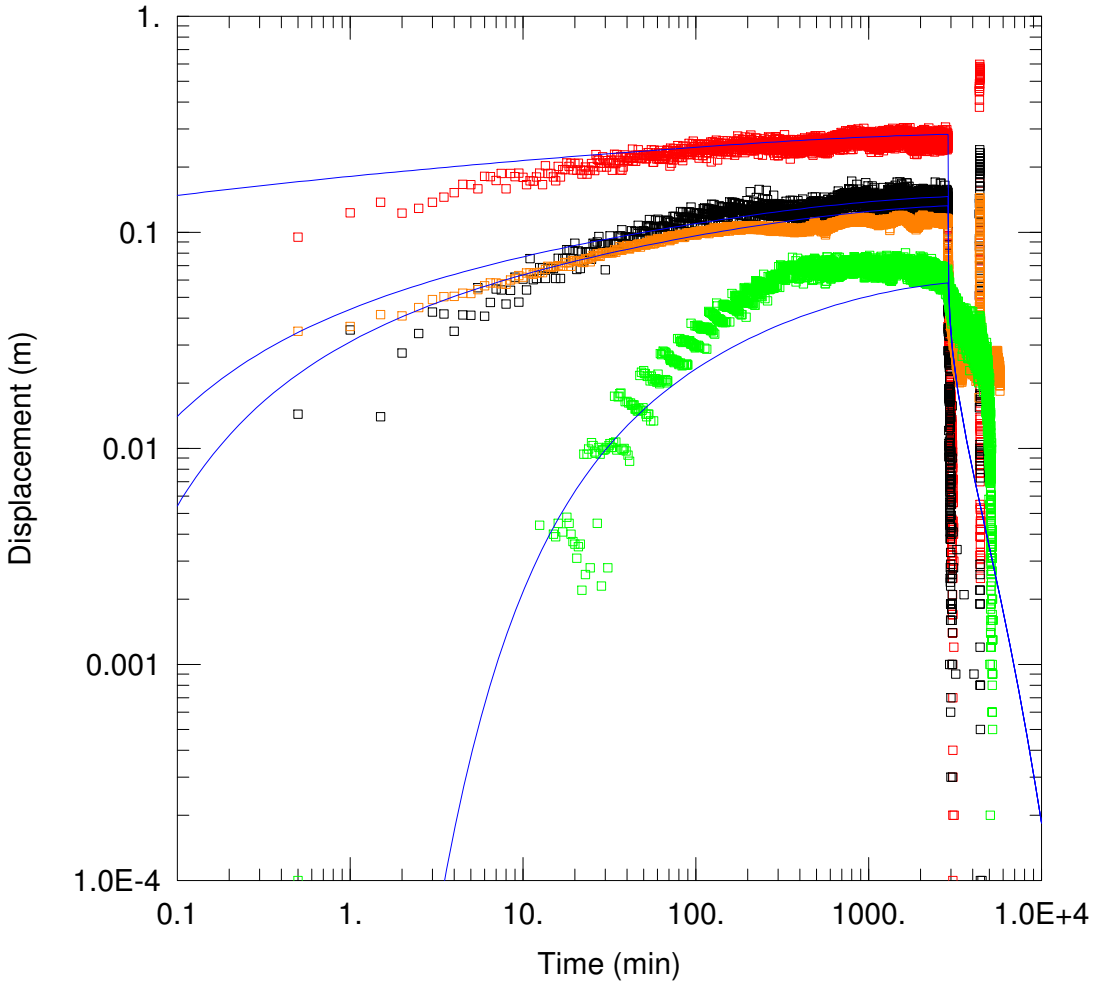
Well Name	X (m)	Y (m)
MDPB0020	654423	7546694
MDPZ9212D	654400	7546690
MDPZ9212S	654386	7546690
MDPZ5355	654392	7546201

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush-Jacob

T = 5782.9 m^2/day
1/B = 0.000282 m^{-1}
b = 42. m

S = 0.01126
Kz/Kr = 0.1



WELL TEST ANALYSIS

Data Set: C:\...\MDPB0020_Leaky_9212S.aqt
Date: 03/17/22 Time: 13:28:21

PROJECT INFORMATION

Company: AQ2
Client: Roy Hill
Project: 171J
Location: Malay Well
Test Well: MDPB0020
Test Date: 10/12/2019

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0020	654423	7546694

Observation Wells

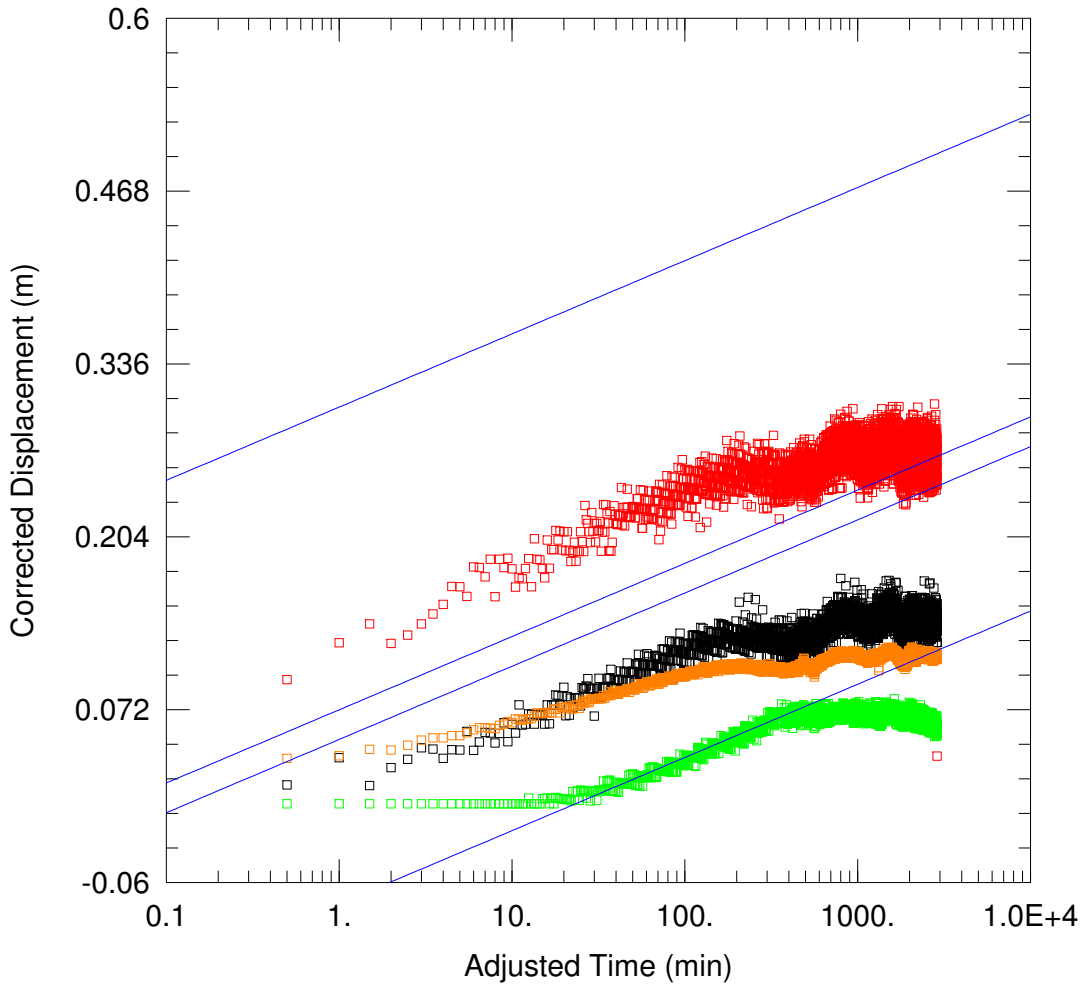
Well Name	X (m)	Y (m)
MDPB0020	654423	7546694
MDPZ9212D	654400	7546690
MDPZ9212S	654386	7546690
MDPZ5355	654392	7546201

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush-Jacob

T = 9510.4 m^2/day
1/B = 0.000282 m^{-1}
b = 42. m

S = 0.001335
Kz/Kr = 0.1



WELL TEST ANALYSIS

Data Set: C:\Users\EJBolton\Documents\Drafts etc\171\Task J\Test Pumping\MDPB0020_CJ_5355.aqt
Date: 03/17/22 Time: 13:06:29

PROJECT INFORMATION

Company: AQ2
Client: Roy Hill
Project: 171J
Location: Malay Well
Test Well: MDPB0020
Test Date: 10/12/2019

AQUIFER DATA

Saturated Thickness: 42. m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0020	654423	7546694

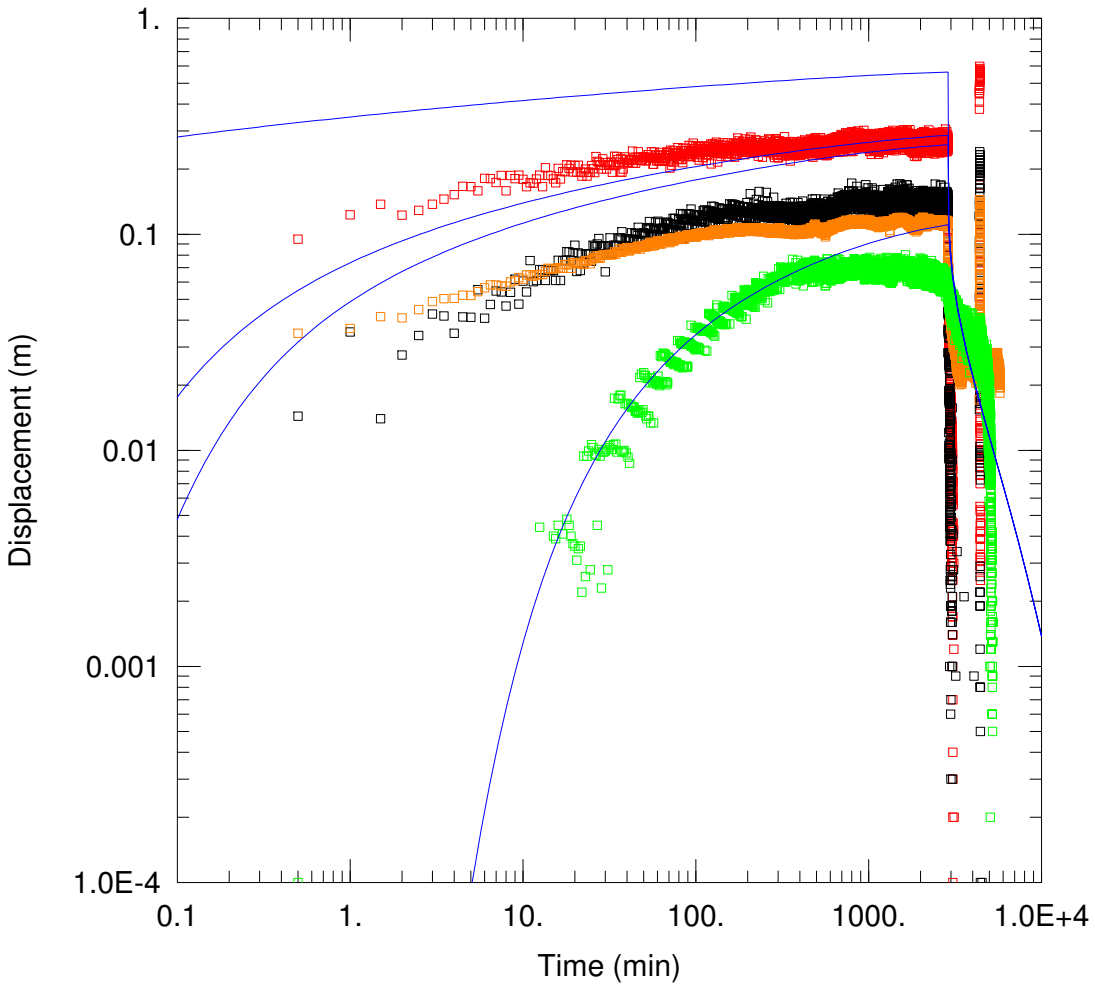
Observation Wells

Well Name	X (m)	Y (m)
MDPB0020	654423	7546694
MDPZ9212D	654400	7546690
MDPZ9212S	654386	7546690
MDPZ5355	654392	7546201

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 5663.1 m^2/day S = 0.000843



WELL TEST ANALYSIS

Data Set: C:\...\MDPB0020_Leaky_5355.aqt
Date: 03/17/22 Time: 13:17:43

PROJECT INFORMATION

Company: AQ2
Client: Roy Hill
Project: 171J
Location: Malay Well
Test Well: MDPB0020
Test Date: 10/12/2019

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0020	654423	7546694

Observation Wells

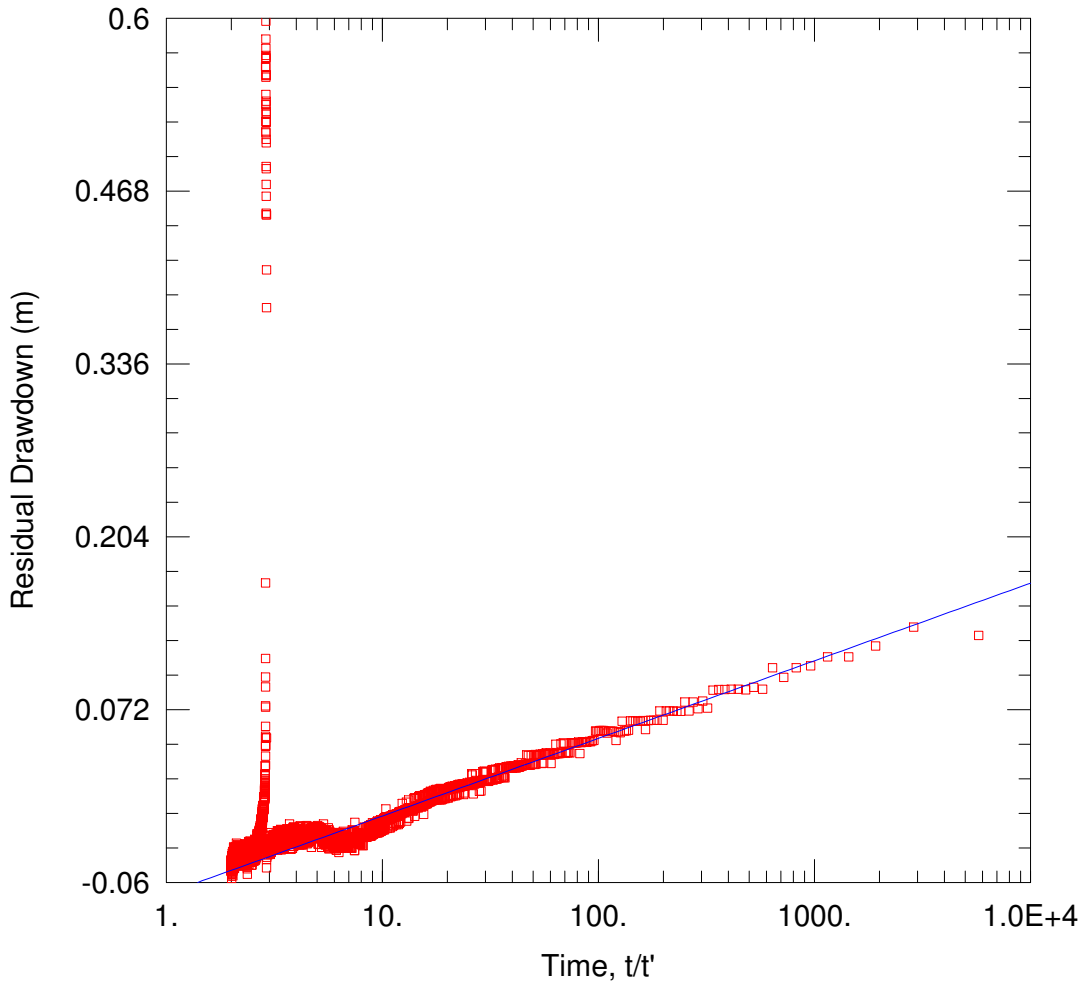
Well Name	X (m)	Y (m)
MDPB0020	654423	7546694
MDPZ9212D	654400	7546690
MDPZ9212S	654386	7546690
MDPZ5355	654392	7546201

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush-Jacob

T = 4739.5 m^2/day
1/B = 0.000282 m^{-1}
b = 42. m

S = 0.001118
Kz/Kr = 0.1



WELL TEST ANALYSIS

Data Set: C:\Users\EJBolton\Documents\Drafts etc\171\Task J\Test Pumping\MDPB0020_rec.aqt
Date: 03/17/22 Time: 13:35:55

PROJECT INFORMATION

Company: AQ2
Client: Roy Hill
Project: 171J
Location: Malay Well
Test Well: MDPB0020
Test Date: 10/12/2019

AQUIFER DATA

Saturated Thickness: 42. m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MDPB0020	654423	7546694

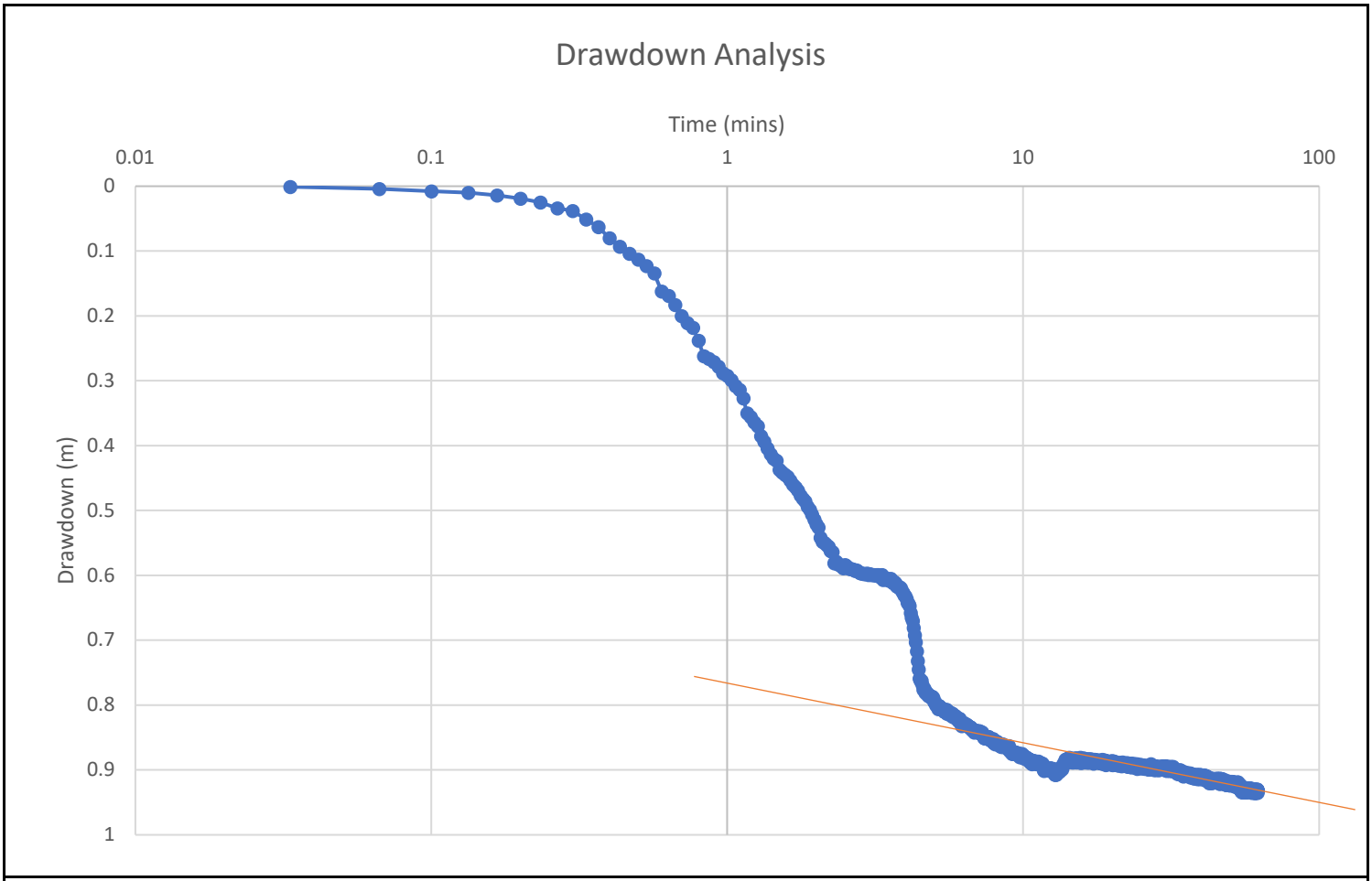
Observation Wells

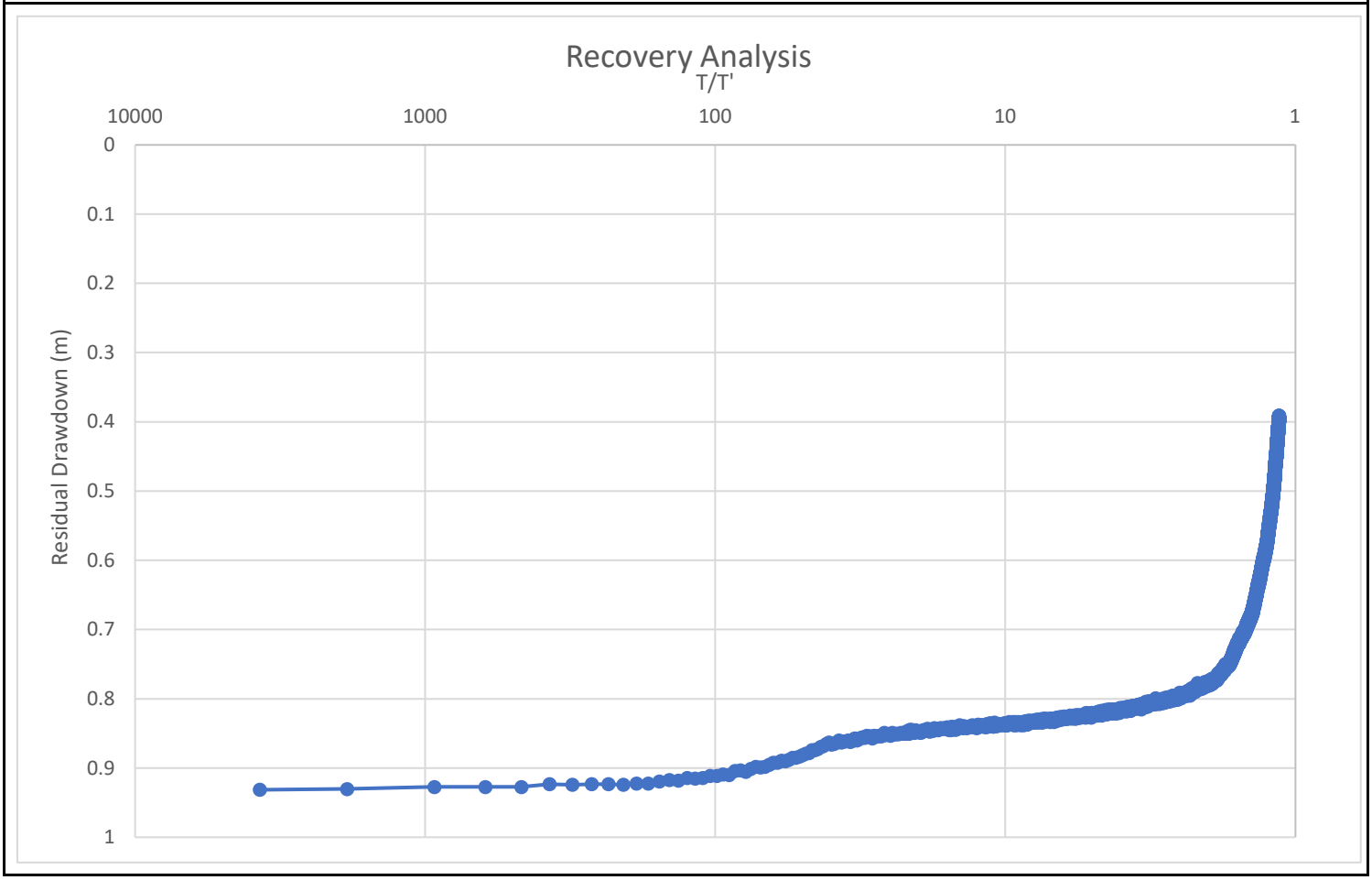
Well Name	X (m)	Y (m)
MDPB0020	654423	7546694

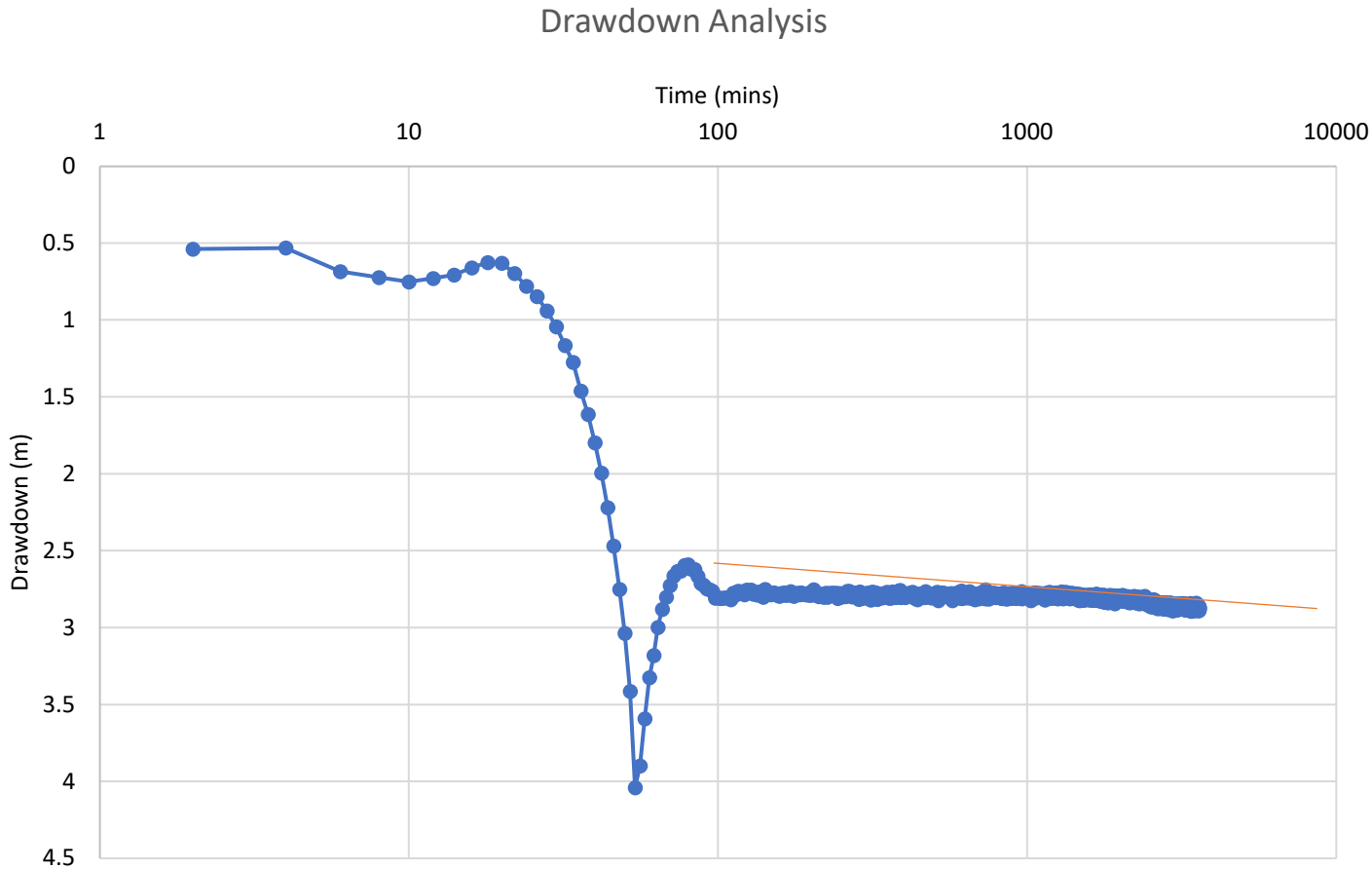
SOLUTION

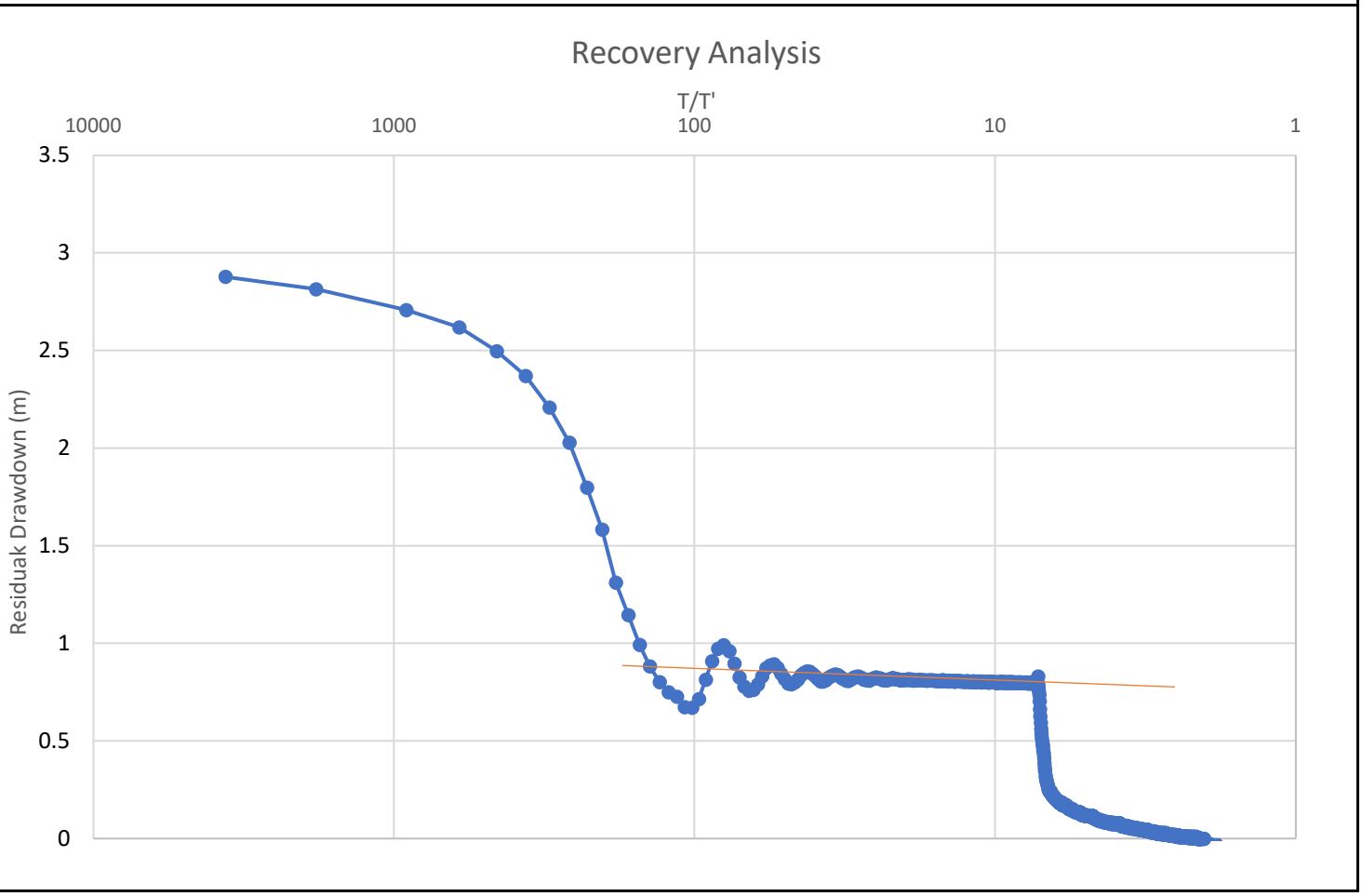
Aquifer Model: Confined Solution Method: Theis (Recovery)

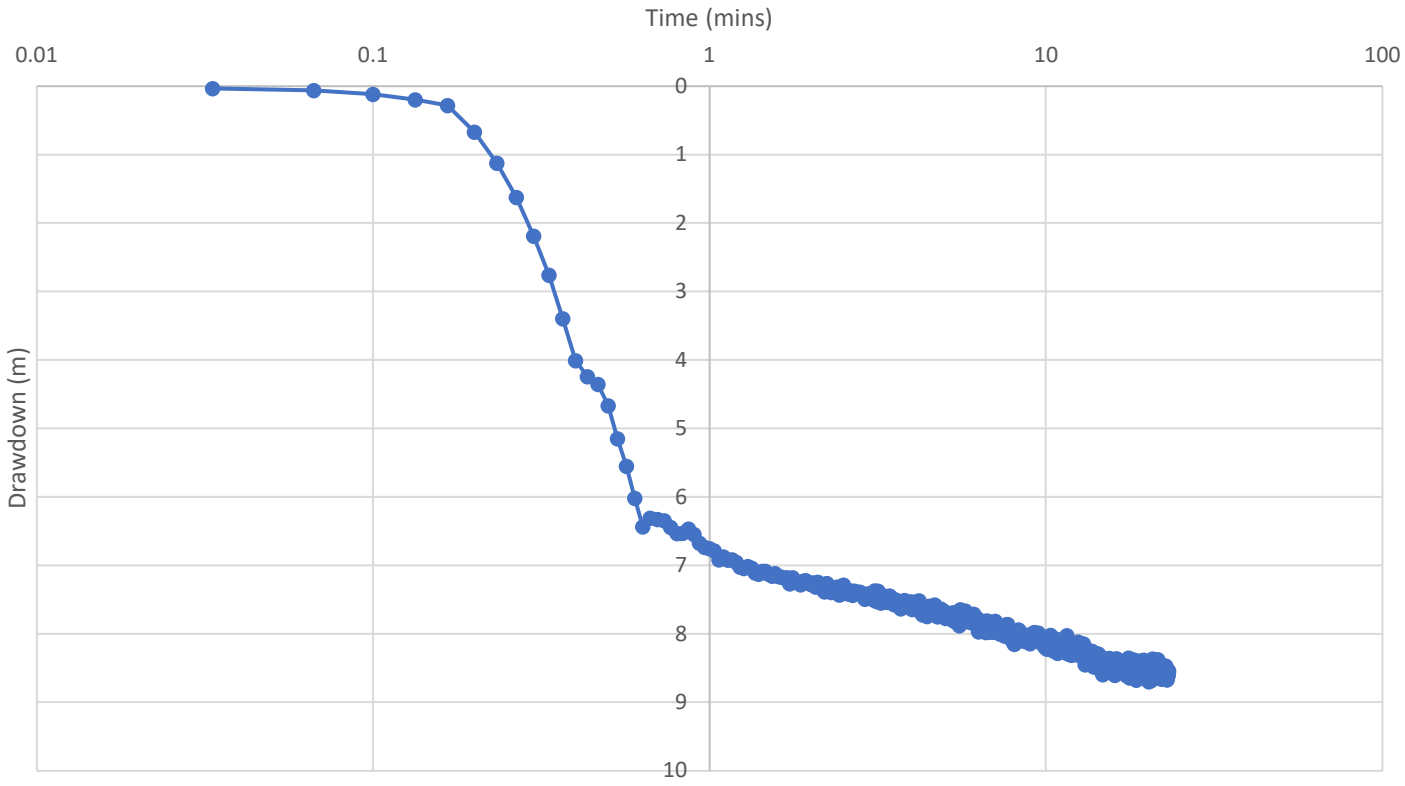
T = 5342.1 m^2/day S/S' = 14.37

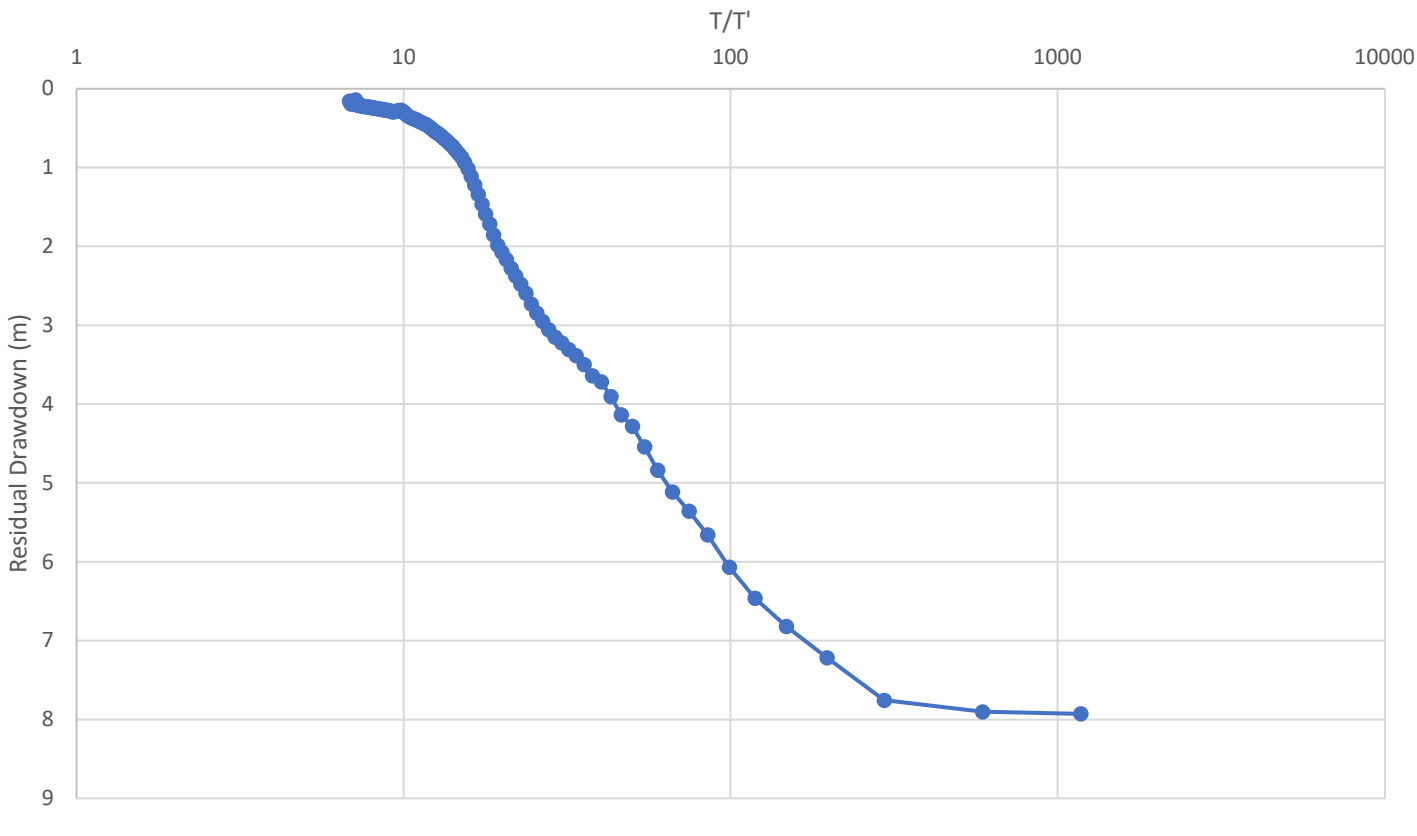

Drawdown Analysis
Time (mins)
0.01
0.1
1
10
100
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Drawdown (m)

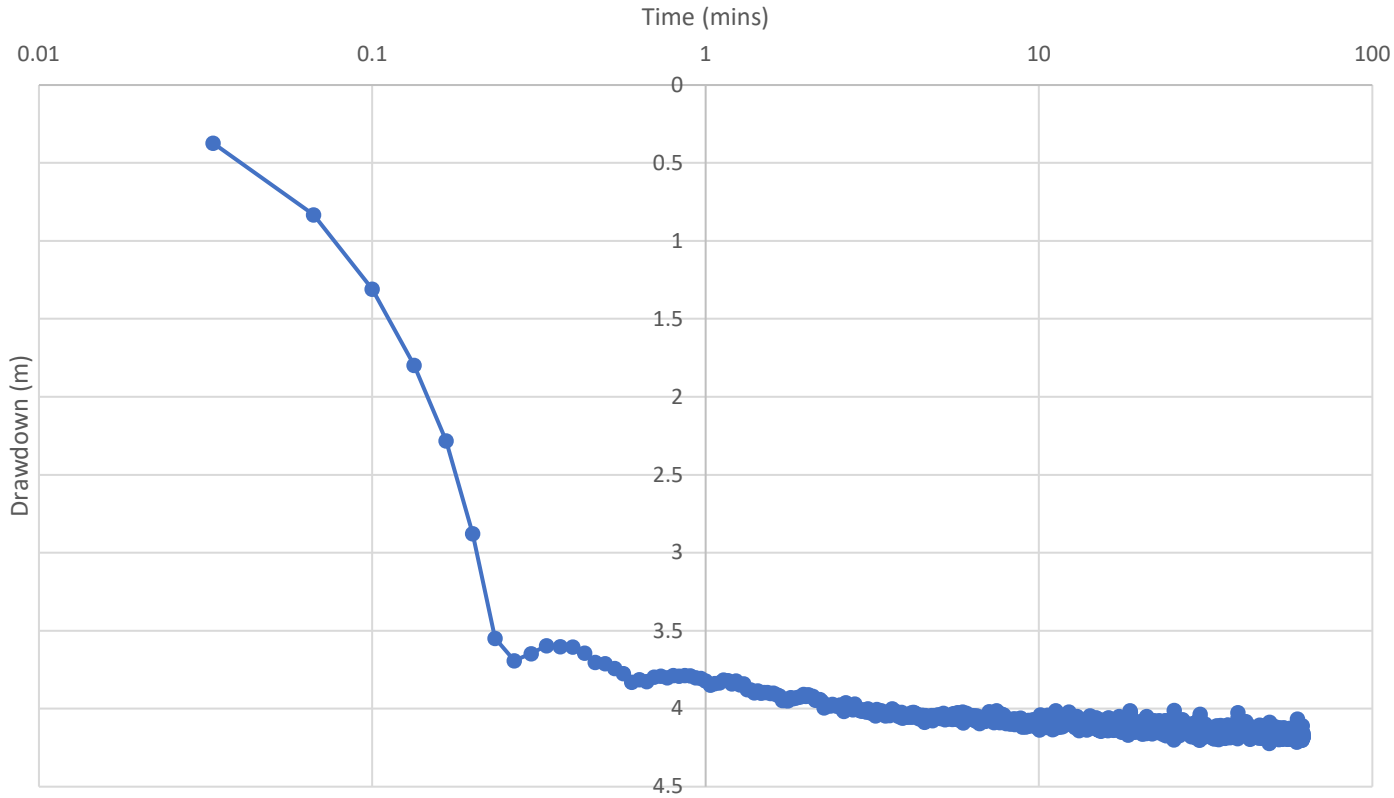

Recovery Analysis
T/T'
10000
1000
100
10
1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Residual Drawdown (m)

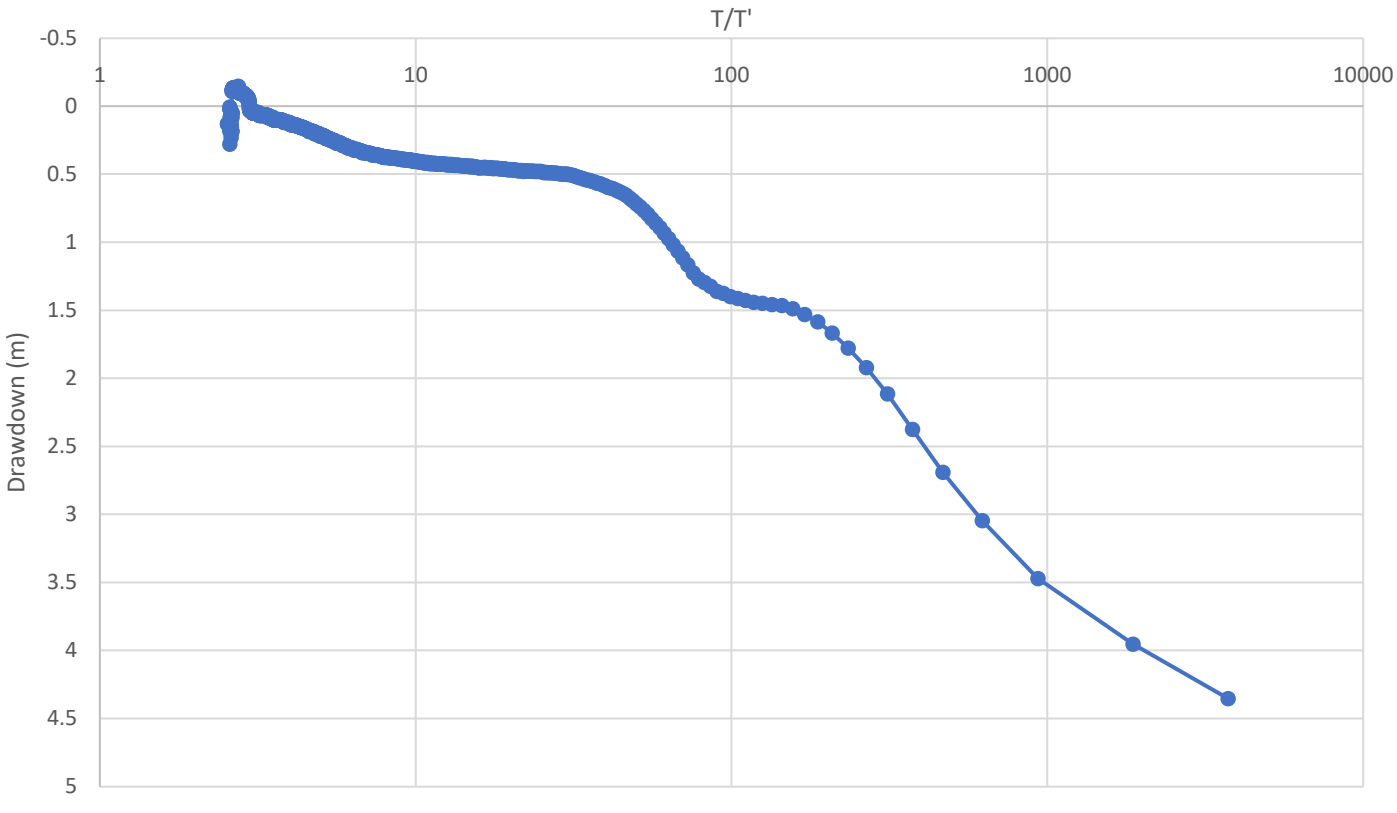

Drawdown Analysis
Time (mins)
1
10
100
1000
10000
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
Drawdown (m)


Recovery Analysis
T/T'
10000
1000
100
10
1
3.5
3
2.5
2
1.5
1
0.5
0
Residuak Drawdown (m)


Drawdown Analysis
Time (mins)
0.01
0.1
1
10
100
Drawdown (m)
0
1
2
3
4
5
6
7
8
9
10


Recovery Analysis
T/T'
1
10
100
1000
10000
Residual Drawdown (m)
0
1
2
3
4
5
6
7
8
9


Drawdown Analysis
Time (mins)
0.01
0.1
1
10
100
Drawdown (m)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5


Recovery Analysis
T/T'
1
10
100
1000
10000
Drawdown (m)
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

APPENDIX G
HYDROCHEMISTRY DATA

WATER QUALITY ANALYSIS - SURFACE WATER

Water Quality Analysis - Surface Water

Bore ID	Sample Date	pH	Conductivity	Total Dissolved Solids	Calcium - Dissolved	Magnesium - Dissolved	Sodium - Dissolved	Potassium - Dissolved	Aluminium - Dissolved	Iron - Dissolved	Chloride	Sulfate	Filterable Reactive Phosphorus	Reactive Silica	Ammonia-N	Nitrate-N	Total Alkalinity	Bicarbonate	Bicarbonate	Carbonate	Hardness
		pH units	uS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg CaCO3/L	mg CaCO3/L	mg HCO3/L	mg CO3/L	mg CaCO3/L
DRAINAGE LINE WATER SAMPLES																					
ANZECC Guideline Value (Upland Rivers)		**6-7.5**							**0.055**			**6.500**	**0.01500**			**55.000**					
SWML01A	2/04/2019	6.7		14000	25	1900	1700	160	<0.1	0.06	6400	1700	<0.01	4.8	1.1	0.02	28	28		<5	7900
SWML01A	17/01/2020	6.6		54	7.5	2	1.4	3.6	<0.1	0.07	<5	2	0.04	7.8	0.39	0.02	34	34		<5	27
SWML01A	3/05/2020	7.6	110	66	13	3.7	5.2	4.9			<5	6	0.1	17	<0.02	2.1	41	41		<5	48
SWML01B	17/03/2021	6.3	170	100	12	2.4	4	6.2	0.12	0.08	<5	11	0.41	12	2.5	2.9	33	33		<5	42
SWML01B	7/07/2022	6.1	280	240	21	5.6	8.5	16	0.015	0.021	14	43	1.8	36		14	<5		<5		75
SWML02	2/04/2019	6.7		5200	8.7	340	1400	32	0.3	0.43	3400	300	<0.01	3.6	<0.02	1.4	7	7		<5	1400
SWML02	17/01/2020	6.2		48	6.4	1.7	1.5	4.1	<0.1	0.08	<5	3	0.11	4.5	0.07	5.8	<5	<5		<5	23
SWML02	4/05/2020	3.7	310	190	15	4.2	2.9	4.6			<5	4	0.12	23	9.5	28	<5	<5		<5	55
SWML02	17/03/2021	6.4	30	18	1.6	0.4	1	2.3	0.95	0.61	<5	2	0.05	9.6	<0.02	1.3	<5	<5		<5	6
SWML05	31/03/2019	8		130	16	1.8	15	5.2	<0.1	<0.01	17	13	0.04	6	1.8	0.71	47	47		<5	47
SWML05	17/03/2021	6.9	40	24	4.8	0.8	0.8	1.9	1.6	0.85	<5	2	<0.01	5.4	<0.02	0.26	19	19		<5	15
SWML05	16/03/2023	6	53	32							2	5		5.6		2.71	<5		<5	<5	11
CLAYPAN WATER SAMPLES																					
ANZECC Guideline Value (Freshwater Lakes)		**6-8**							**0.055**			**6.500**	**0.0500**			**0.350**					
SWML03	26/04/2019	7		1600	4.8	4.8	620	29	<0.1	<0.01	1300	170	0.01	27	0.22	<0.01	50	50		<5	32
SWML03	3/05/2020	7.1	200	120	5.4	1.2	55	4.1			11	<1	0.05	16	0.67	<0.01	85	85		<5	18
SWML03	12/12/2021	8.3	260	260	5.4	2.4	44	9.6	1.8	2.8	27	39	N.A.	N.A.		N.A.	92		110	<5	23
SWML03	7/07/2022	7.7	100	6200	5	2.8	22	6.3	5.7	14	30	43	0.42	29		<0.05	65		79		24
SWML04	1/04/2019	7.2		19000	35	180	950	51	<0.1	0.06	1600	230	<0.01	11	6	0.05	120	120		<5	830
SWML04	28/01/2020	7.1		170							25	40	0.12	22	1.2	0.51	110	110		<5	340
SWML04	3/05/2020	8.2	390	230	4.3	1.8	79	17			54	17	0.07	15	<0.02	1.4	130	130		<5	18
SWML04	7/07/2022	8	290	3500	3.9	2.5	52	13	5.1	10	64	30	0.44	23		1.6	86		100		20
SWML04	16/03/2023	7.9	280	4700							54	40		29		0.8584	100		130	<5	200
SWML09	18/05/2023	7.2	180	870	7.4	2.8	23	5.8	1.9	1.3	19	25	0.077	24		1.3	41		50	<5	30
SWML13	18/05/2023	7.3	290	5500	13	6.4	48	11	7.4	8.2	56	7	0.15	27		1.4	100		130	<5	57
OPPORTUNISTIC WATER SAMPLES																					
Two Mile Well SW	16/03/2023	7.5	210	9600							34	37		24		0.045	150		180	<5	850
SWM01 US POOL	18/05/2023	7.9	220	160	24	5.2	6.2	11	0.005	0.094	6	<1	<0.002	13		<0.05	100		120	<5	82

Water Quality Analysis - Surface Water

Bore ID	Sample Date	Ammonium, NH4	Nitrite-N	Fluoride by ISE	Silicon, Si-Dissolved	Sulfur, S	Iron - Total	Aluminium - Total	Mercury - Total	Arsenic, As-Dissolved	Barium, Ba-Dissolved	Cadmium, Cd-Dissolved	Chromium, Cr-Dissolved	Molybdenum, Mo-Dissolved	Lead, Pb-Dissolved	Total Suspended Solids (TSS)	Selenium - Dissolved	Selenium - Total	Vanadium, V-Dissolved	Zinc - Total	Zinc - Dissolved	Total Kjeldahl Nitrogen	Total Phosphorus (Kjeldahl Digestion) as P
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
DRAINAGE LINE WATER SAMPLES																							
ANZECC Guideline Value (Upland Rivers)		**0.013**	**0.25**					**0.055**	**0.0006**								**0.011**	**0.011**		**0.008**	**0.008**		**0.02**
SWML01A	2/04/2019																						
SWML01A	17/01/2020								<0.0002									<0.001			0.04	1.2	
SWML01A	3/05/2020						77	34	<0.0002									0.001		0.33		0.2	
SWML01B	17/03/2021																<0.001				0.036	2.3	
SWML01B	7/07/2022	0.17															<0.001				0.017		2.2
SWML02	2/04/2019																						
SWML02	17/01/2020								<0.0002									<0.001			0.010	1.2	
SWML02	4/05/2020						6.6	3.3	<0.0002									<0.001		0.16		10.00	
SWML02	17/03/2021																<0.001				<0.005	0.5	
SWML05	31/03/2019																						
SWML05	17/03/2021																<0.001				<0.005	0.5	
SWML05	16/03/2023		0.1	<0.1	2.7	2	0.12	0.041			0.018			<0.001		N/A		<0.001		0.03			
CLAYPAN WATER SAMPLES																							
ANZECC Guideline Value (Freshwater Lakes)		**0.01**	**0.35**					**0.055**	**0.0006**			**0.0002**					**0.011**	**0.011**		**0.008**	**0.008**		**0.01**
SWML03	26/04/2019									0.009		<0.002	<0.01		<0.01		<0.001				<0.01	1.5	
SWML03	3/05/2020						500	230	0.0002									0.003		0.97		1.4	
SWML03	12/12/2021	N.A.			18	6.1													0.017		0.034		
SWML03	7/07/2022	0.88															<0.001				0.015		6
SWML04	1/04/2019																						
SWML04	28/01/2020																					9.2	
SWML04	3/05/2020						170	58	<0.0002									0.001		0.37		2	
SWML04	7/07/2022	1.1															<0.001				0.015		3.30
SWML04	16/03/2023		0.8	0.1	220	1	440	140			0.630			<0.001		1500		<0.001		0.23			
SWML09	18/05/2023	1.2	0.18	<0.1	13	9.0	280	100	<0.00005	<0.001	0.063	<0.001	<0.001	<0.001	0.002	33,000	<0.001	<0.002	<0.001	0.26	<0.005		17
SWML13	18/05/2023	4.2	0.52	<0.1	23	2.4	970	450	<0.00005	0.002	0.190	<0.001	0.006	<0.001	0.009	40,000	<0.001	<0.002	<0.001	0.9	0.013		23
OPPORTUNISTIC WATER SAMPLES																							
Two Mile Well SW	16/03/2023		1	<0.1	350	1.6	1100	430			5.5			<0.001		85,000		<0.001		0.48			
SWM01 US POOL	18/05/2023	0.04	<0.05	<0.1	6.0	0.2	0.730	0.130	<0.00005	<0.001	0.060	<0.001	<0.001	<0.001	<0.001	<5	<0.001	0.001	<0.001	0.064	0.047		0.05

BASIC WATER QUALITY ANALYSIS – GROUNDWATER

Lab Report	Bore ID	Sample Date	Sample Type	Sample Depth	pH	Conductivity	Total Dissolved Solids	Calcium - Dissolved	Magnesium - Dissolved	Sodium - Dissolved	Potassium - Dissolved	Aluminium - Dissolved	Iron - Dissolved	Manganese - Dissolved	Chloride	Sulfate	Filterable Reactive Phosphorus	Reactive Silica	Ammonia-N	Nitrate-N	Total Alkalinity	Bicarbonate	Bicarbonate	Carbonate	Hardness
					pH units	uS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg CaCO3/L	mg CaCO3/L	mg HCO3/L	mg CO3/L	mg CaCO3/L
PE071720	MDPB004	7/10/2012	Pumping Test		7.2	870	570	40	31	78	16			0.022	120	100		63		35	150		180	<1	
PE071720	MDPB004	8/10/2012	Pumping Test		7.2	860	570	42	31	80	17			0.012	110	110		64		36	140		170	<1	
PE071585	MDPB005	1/10/2012	Pumping Test		7.1	800	560	54	36	64	17			0.007	78	140		52		12	170		210	<1	
PE071585	MDPB005	2/10/2012	Pumping Test		7.1	800	520	51	36	61	16			0.006	78	140		54		12	170		200	<1	
PE071720	MDPB006	4/10/2012	Pumping Test		6.2	740	510	31	23	46	23			0.12	74	180		54		15	31		38	<1	
PE071720	MDPB006	5/10/2012	Pumping Test		6.2	680	490	29	22	45	22			0.049	70	170		54		17	32		39	<1	
19-04258	MDPZ7457A	13/03/2019	Airlift		6.9		9000	270	360	2800	210	<0.1	0.02	2	3400	2200	0.01	13	0.02	0.19	390	390		<5	2200
19-04258	MDPZ7457B	14/03/2019	Airlift		7.4		6000	250	230	1800	140	<0.1	0.02	<0.01	2500	1700	0.09	54	<0.02	3.6	330	330		<5	1600
19-04258	MDPZ7458A	15/03/2019	Airlift		7.3		7600	250	300	2900	170	<0.1	0.01	0.02	3700	1800	0.04	34	0.02	4.6	400	400		<5	1900
19-04258	MDPZ7457C	16/03/2019	Airlift		7.5		3800	180	180	1100	92	<0.1	0.01	<0.01	1700	890	0.07	54	<0.02	4.9	310	310		<5	1200
19-04258	MDPZ7458B	16/03/2019	Airlift		7.5		7900	240	290	2400	180	<0.1	0.01	0.02	3800	1800	0.06	40	<0.02	3.8	410	410		<5	1800
19-04258	MDPZ7458C	16/03/2019	Airlift		7.7		8500	160	300	2600	180	<0.1	<0.01	<0.01	3100	1600	0.14	72	<0.02	3.7	540	540		<5	1600
19-04258	MDPZ7451B	17/03/2019	Airlift		7.2		9800	350	360	2500	200	<0.1	0.03	0.44	3600	2400	0.05	42	<0.02	4	390	390		<5	2400
19-04258	MDPZ7451C	17/03/2019	Airlift		7.2		1800	110	92	430	44	<0.1	0.01	0.03	580	430	0.05	47	<0.02	6.9	240	240		<5	650
19-04258	MDPZ7452B	17/03/2019	Airlift		7.5		4700	160	180	1300	110	<0.1	0.02	<0.01	1800	1000	0.05	57	<0.02	6	400	400		<5	1100
19-04258	MDPZ7449B	18/03/2019	Airlift		7		900	78	55	170	23	<0.1	0.02	<0.01	230	240	0.03	54	<0.02	6.3	180	180		<5	420
19-04258	MDPZ7459	18/03/2019	Airlift		7.7		350	40	21	41	<0.1	<0.1	<0.01	<0.01	31	19	0.04	54	<0.02	1.6	230	230		<5	190
19-04524	MDPZ7462A	22/03/2019	Airlift		8		1800	42	64	420	56	<0.1	0.04	<0.01	620	380	0.04	53	<0.02	4.3	360	360		<5	370
19-04524	MDPZ7462B	22/03/2019	Airlift		7.8		3400	130	150	630	74	<0.1	0.03	<0.01	1200	680	0.05	57	<0.02	4.9	300	300		<5	940
19-04524	MDPZ7462C	22/03/2019	Airlift		7.9		2600	130	140	540	70	<0.1	0.04	<0.01	890	480	0.05	63	<0.02	4.9	280	280		<5	900
19-05368	MDPZ7463	1/04/2019	Airlift		7.9		4300	210	170	1300	93	<0.1	<0.01	<0.01	1500	1000	0.04	43	<0.02	4.1	350	350		<5	1200
19-05776	MDPZ7464	5/04/2019	Airlift		7.9		2900	140	140	860	100	<0.1	<0.01	0.12	850	620	0.05	35	0.03	2.1	370	370		<5	930
19-05776	MDPZ7465	9/04/2019	Airlift		7.6		990	84	57	130	33	<0.1	0.03	0.05	290	240	0.03	47	0.03	5.3	130	130		<5	440
19-06249	MDPZ7466	26/04/2019	Airlift		4.3		1100	170	160	84	82	2	<0.01	6.9	150	720	0.03	60	0.07	0.43	<5	<5		<5	1100
19-06249	MDPZ7467	26/04/2019	Airlift		8		680	100	87	90	41	<0.1	<0.01	<0.01	170	290	0.03	42	<0.02	1.9	170	170		<5	630
19-06249	MDPZ7468A	26/04/2019	Airlift		7.6		11000	390	460	3200	290	0.1	<0.01	0.04	5200	2600	0.07	45	0.06	1.7	390	390		<5	2900
19-06249	MDPZ7468B	26/04/2019	Airlift		7.6		9400	390	420	2700	220	<0.1	<0.01	<0.01	4900	2300	0.04	45	0.03	2.5	350	350		<5	2700
19-06249	MDPZ7468C	26/04/2019	Airlift		7.6		6900	300	320	2000	180	<0.1	<0.01	0.02	3500	2000	0.06	47	0.03	3.6	330	330		<5	2100
19-06460	MDPZ7469A	29/04/2019	Airlift		7.5		9100	280	290	2500	190	<0.1	<0.01	1.5	3700	2100	0.03	21	0.06	0.22	310	310		<5	1900
19-06460	MDPZ7469B	29/04/2019	Airlift		7.8		1600	140	110	370	53	<0.1	<0.01	0.05	630	340	0.04	46	0.07	5.8	190	190		<5	800
19-06460	MDPZ7469C	29/04/2019	Airlift		8		1600	130	100	350	50	<0.1	<0.01	0.01	550	350	0.04	45	0.06	6.1	220	220		<5	740
19-07588	MDPB0012	8/05/2019	Airlift		8.1		1100	93	64	180	33	<0.1	<0.01	<0.01	310	250	0.03	41	<0.02	5.9	170	170		<5	500
19-07588	MDPB0013	16/05/2019	Airlift		8.2		3800	200	130	830	86	<0.1	<0.01	0.16	1900	610	0.03	21	0.03	2.5	250	250		<5	1000
19-08491	MDPZ7460C	26/05/2019	Airlift		7.2		2500	170	160	540	54	<0.1	0.08	<0.01	1000	490	0.05	48	<0.02	4.7	200	200		<5	1100
19-08491	MDPZ7450C	27/05/2019	Airlift		7.8		350	30	21	57	6.4	<0.1	<0.01	<0.01	52	24	0.09	63	<0.02	0.97	270	270		<5	160
19-08491	MDPZ7452C	27/05/2019	Airlift		7.4		3800	160	160	1200	89	<0.1	0.03	<0.01	1700	940	0.07	56	<0.02	5.4	410	410		<5	1100
19-08491	MDPZ7453C	27/05/2019	Airlift		7.2		10000	490	540	2400	210	<0.1	0.02	0.01	4300	2500	0.11	72	<0.02	7	370	370		<5	3400
19-08491	MDPZ7456C	27/05/2019	Airlift		7		1900	150	120	450	44	<0.1	<0.01	<0.01	820	410	0.06	50	<0.02	4.6	160	160		<5	870
19-08491	MDPZ7453B	28/05/2019	Airlift		7.2		10000	460	530	2900	210	<0.1	<0.01	<0.01	4500	2800	0.13	69	<0.02	4	390	390		<5	3300
19-08491	MDPZ7450B	29/05/2019	Airlift		7.3		600	93	62	68	12	<0.1	<0.01	<0.01	150	160	0.06	48	<0.02	5	310	310		<5	490
19-08491	MDPZ7456B	29/05/2019	Airlift		7		2200	130	100	480	37	<0.1	0.25	<0.01	900	430	0.05	46	<0.02	5.3	160	160		<5	740
19-08491	MDPZ7460B	29/05/2019	Airlift		7.2		2500	170	170	560	56	<0.1	<0.01	<0.01	1100	470	0.04	46	<0.02	4.9	190	190		<5	1100
19-08491	MDPZ7450A	30/05/2019	Airlift		7.2		530	94	66	110	15	<0.1	0.01	<0.01	220	170	0.05	49	<0.02	3.7	340	340		<5	510
19-08491	MDPZ7460A	30/05/2019	Airlift		7.3		3000	120	130	700	55	<0.1	0.04	0.21	1400	540	0.02	23	0.03	0.46	280	280		<5	840
19-08491	MDPZ7449A	31/05/2019	Airlift		7.1		920	170	86	85	27	<0.1	<0.01	0.21	240	320	<0.01	12	<0.02	<0.01	390	390		<5	780
19-12584	MDPZ7451A	17/07/2019	Airlift		7.2		12000	320	410	2900	300	<0.1	0.01	1	5000	2600	0.04	37	0.29	<0.01	380	380		<5	2400
19-12584	MDPZ7470C	24/07/2019	Airlift		8.1		3600	130	110	1000	130	<0.1	<0.01	<0.01	1600	650	0.09	66	0.07	3.9	350	350		<5	860
19-12584	MDPZ7470A	25/07/2019	Airlift		7.7		5500	200	190	1400	140	<0.1	<0.01	0.55	2200	880	0.05	42	0.05	1.7	330	330		<5	1300
19-12584	MDPZ7470B	25/07/2019	Airlift		7.8		3700	130	120	1000	120	<0.1	<0.01	<0.01	1700	650	0.07	57	0.03	3.7	340	340		<5	900
19-12584	MDPZ7471A	31/07/2019	Airlift		7.8		5500	170	230	1500	150	<0.1	<0.01	<0.01	2300	1100	0.07	49	0.09	4.2	390	390		<5	1200
19-12584	MDPZ7471B	31/07/2019	Airlift		7.9		6100	200	270	1600	140	<0.1	<0.01	<0.01	2700	1200	0.07	44	0.08	3.5	390	390		<5	1700
19-12584	MDPZ7471C	31/07/2019	Airlift		8.1		4600	120	170	1300	110	<0.1	<0.01	<0.01	2000	880	0.08	59	0.13	4.7	430	430		<5	1100
19-13311	MD5455	3/08/2019	Airlift		7.8		940	110	79	270	35	<0.1	<0.01	0.04	410	340	0.01	24	<0.02	2.9	220	220		<5	600
19-13311	MD5461	3/08/2019	Airlift		7.4		1200	96	76	310	42	<0.1	<0.01	<0.01	460	270	0.03	48	<0.02	6.3	230	230		<5	550
19-13311	MD5382	4/08/2019	Airlift		7.9		460	49	31	91	18	<0.1	<0.01	0.03	100	110	0.02	41	<0.02	2.2	150	150		<5	250
19-13311	MD6605	4/08/2019	Airlift		8		620	130	57	99	30	<0.1	<0.01	0.21	160	310	0.01	22	<0.02	0.76	200	200		<5	560
19-13311	MDPZ7449C	11/08/2019	Airlift		6.8		5000	700	400	700	120	<0.1	<0.01	<0.01	2100	1400	0.07	81	<0.02	14	120	120		<5	3400
19-15185	MDPZ7456A	5/09/2019	Airlift		7.5		2100	150	120	460	62	<0.1	<0.01	<0.01	840	410	0.04	43	<0.02	4.8	230	230		<5	870
19-15185	MDPZ7453A	6/09/2019	Airlift		7.3		15000	530	510	4500	290	<0.1	<0.01	<0.01	5700	3200	0.09	57	<0.02	1.5	360	360		<5	3400
19-15185	MDPB0015	9/09/2019	Pumping Test		7.4		4600	170	160	1200	140	<0.1	<0.01	<0.01	1600	870	0.07	62	<0.02	5.4	380	380		<5	1100
19-16376	MDPB0011	19/09/2019	Pumping Test		7.4		530	54	45	66	12	<0.1	0.34	<0.01	100	49	0.06	60	<0.02	1.8	230	230		<5	320
19-16376	MDPB0012	24/09/2019	Pumping Test		6.9		890	67	54	190	36	<0.1	0.1	<0.01	280	250	0.04	49	<0.02	6.5	160	160		<5	390
19-17181	MDPB0013	30/09/2019	Pumping Test		7.3		2700	150	160	750	78	<0.1	0.03	0.15	1100	550	0.03	37	<0.02	3.1	330	330		<5	1000
19-17181	MDPB0014	9/10/2019	Pumping Test		7.2		3400	180	210	880	110	<0.1	<0.01	<0.01	1300	760	0.06	60	<0.02	5.1	320	320		<5	1300
19-19463	MDPZ7454	10/11/2019	Hydrasleeve	50	6	940	590	39	29	43	27	<0.1	<0.01	0.55	95	220	0.02	29	0.18	0.93	50	50		<5	220
19-19463	MDPZ7459	12/11/2019	Hydrasleeve	20	7.6	500	300	43	21	23	1.8	<0.1	<0.01	<0.01	35	10	0.07	49	<0.02	1.5	210	210		<5	190
19-19463	MDPZ7462A	12/11/2019	Hydrasleeve	115	7	11000	7700	330	250	1700	160	<0.1	<0.01	4.4	3100	1500	0.04	24	0.83	0.12	430	430		<5	1900
19-19463	MDPZ7462B	12/11/2019	Hydrasleeve	55	7.2	5200	3000	150	150	670	67	<0.1	<0.01	<0.01	1100	650	0.07	55	<0.02	5	320	320		<5	990
19-19463	MDPZ7462C	12/11/2019	Hydrasleeve	30	7.4	4500	2700	160	140	570	52	<0.1	<0.01	<0.01	1100	550	0.06	56	<0.02	4.2	280	280		<5	980
19-19463	MDPZ7463 Lower	12/11/2019	Hydrasleeve	80	7.1	8600	5700	210	210	1300	130	<0.1	<0.01	<0.01	2400	1300	0.05	40	<0.02	2.8	340	340		<5	1400
19-19463	MDPZ7463 Upper	12/11/2019	Hydrasleeve	15	7.2	3700	2300	110	86	550	55	<0.1	<0.01	<0.01	790	560	0.05	50	<0.02	3.5	360	360		<5	630
19-19463	MDPZ7464 Lower	12/11/2019	Hydrasleeve	85	7.2	15000	11000	290	400	2900	290	<0.1	<0.01	0.06	4400	2500	0.03	17	<0.02	0.13	330	330		<5	2400
19-19463	MDPZ7464 Upper	12/11/2019	Hydrasleeve	15	7.3	2200	1200	79	65	280	30	<0.1	<0.01	<0.01	380	240	0.05	42	<0.02	1.5	370	370		<5	470
19-19463	MDPZ7468A	12/11/2019	Hydrasleeve	85	7	19000	15000	370	520	3600	390	<0.1	<0.01	1.6	5600	3200	0.02	10	0.06	<0.01	360	360		<5	3100
19-19463	MDPZ7468B	12/11/2019	Hydrasleeve	60	7.3	14000	10000	280	360	2500	260	<0.1	<0.01	<0.01	3900	2200	0.05	37	<0.02	2.1	340	340		<5	2200
19-19463	MDPZ7468C	13/11/2019	Hydrasleeve	30	7	10000	6300	200	230	1600	180	<0.1	<0.01	<0.01	2500	1600	0.06	40	<0.02	3.6	300	300		<5	1400
19-19463	MDPZ7471B	12/11/2019	Hydrasleeve	55	7.3	8700	5600	190	230	1400	140	<0.1	<0.01	0.02	2400	1200	0.06	49	<0.02	4.3	390	390		<5	1400
19-19463	MDPZ7471C	12/11/2019	Hydrasleeve	15	7.4	8000	5000	140	180	1300	110	<0.1	<0.01	<0.01	2200	1000	0.08	62	<0.02	4.4	390	390		<5	1100
19-19463	MDPZ7471A	13/11/2019	Hydrasleeve	72	7.3	8500	5300	160	200	1400	140	<0.1	<0.01	0.03	2300	1100	0.06	51	0.02	4.2	390	390		<5	1200
19-19463	MDPZ7457A	13/11/2019	Hydrasleeve	90	7	14000	10000	260	330	2700	260	<0.1	<0.01	0.96	4100	2100	0.02	14	<0.02	0.17	380	380		<5	2000
19-19463	MDPZ7457B	13/11/2019	Hydrasleeve	45	7.3	11000	7600	240	220	2000	200	<0.1	<0.01	<0.01	3000	1700	0.1	50	<0.02	2	360	360		<5	1500
19-19463	MDPZ7457C	13/11/2019	Hydrasleeve	28	7.4	7200	4700	190	160	1100	130	<0.1	<0.01	<0.01	1800	970	0.09	59	<0.02	3.8	360	360		<5	1100
19-19463	MDPZ7458A	13/11/2019	Hydrasleeve	68	7.3	12000	8500	240	270	2300	200	<0.1	0.02	0.01	3600	1700	0.06	35	<0.02	4.1	400	400		<5	1700
19-19463	MDPZ7458B	13/11/2019	Hydrasleeve	50	7.3	12000	9800	240	290	2700	250	<0.1	<0.01	0.05	3900	1800	0.07	41	<0.02	3.4	400	400		<5	1800
19-19463	MDPZ7458C	13/11/2019	Hydrasleeve	8	7.7	11000	8100	130	230	2200	200	<0.1	<0.01	<0.01	3400	1400	0.12	70	0.04	4.3	510	510		<5	1300
19-19463	MDPZ7460A	13/11/2019	Hydrasleeve	85	7.3	5900	3400	140	120	890	110	<0.1	<0.01	0.33	1500	670	0.02	23	0.14	<0.01	290	290		<5	840
19-19463	MDPZ7460B	13/11/2019	Hydrasleeve	49	7.2	4500	2700	130	100	580	86	<0.1	<0.01	0.02	1100	480	0.04	47	0.53	3.7	200	200		<5	740
19-19463	MDPZ7460C	13/11/2019	Hydrasleeve	25	7.2	4100	2600	130	110	540	78	<0.1	<0.01	<0.01	1100	470	0.06	47	<0.02	4.9	190	190		<5	780
19-19463	MDPZ7469A	13/11/2019	Hydrasleeve	100	6.4	15000	11000	240	340	2700	240	<0.1	0.26	4.3	4300	2300	0.02	12	0.04	0.02	290	290		<5	2000
19-19463	MDPZ7469B	13/11/2019	Hydrasleeve	75	7	3100	1800	100	81	360	62	<0.1	<0.01	<0.01	750	380	0.04	46	<0.02	6.2	180	180		<5	580
19-19463	MDPZ7469C	13/11/2019	Hydrasleeve	35	7.4	2500	1700	97	78	280	56	<0.1	<0.01	<0.01	580	340	0.04	48	<0.02	6.1	190	190		<5	560
19-19463	MDPZ7470A	13/11/2019	Hydrasleeve	90	7.2	8500	5000	170	170	1300	160	<0.1	<0.01	0.85	2300	930	0.05	44	<0.02	2.5	320	320		<5	1100
19-19463	MDPZ7470B	13/11/2019	Hydrasleeve	45	7.4	6100	3600	120	100	940	130	<0.1	<0.01	<0.01	1400	660	0.1	60	<0.02	4	320	320		<5	710
19-19463	MDPZ7470C	13/11/2019	Hydrasleeve	20	7.3	5700	3600	120	100	950	150	<0.1	<0.01	0.04	1500	690	0.12	59	<0.02	3.6	340	340		<5	710
19-19847	MDPZ7449A	16/11/2019	Hydrasleeve	65	7	1800	1200	130	70	170	29	<0.1	0.01	0.19	210	280	0.01	13	0.05	<0.01	380	380		<5	610
19-19847	MDPZ7449B	16/11/2019	Hydrasleeve	25	6.9	1600	1100	73	56	180	28	<0.1	<0.01	<0.01	320	230	0.04	51	<0.02	6	170	170		<5	410
19-19847	MDPZ7449C	16/11/2019	Hydrasleeve	9	6.8	8100	8200	510	400	730	96	<0.1	<0.01	<0.01	2100	1500	0.15	73	<0.02	13	120	120		<5	2900
19-19847	MDPZ7450B	16/11/2019	Hydrasleeve	35	7.2	1300	870	64	50	130	13	<0.1	<0.01	<0.01	180	170	0.03	49	<0.02	4.5	300	300		<5	370

Lab Report	Bore ID	Sample Date	Sample Type	Sample Depth	pH	Conductivity	Total Dissolved Solids	Calcium - Dissolved	Magnesium - Dissolved	Sodium - Dissolved	Potassium - Dissolved	Aluminium - Dissolved	Iron - Dissolved	Manganese - Dissolved	Chloride	Sulfate	Filterable Reactive Phosphorus	Reactive Silica	Ammonia-N	Nitrate-N	Total Alkalinity	Bicarbonate	Bicarbonate	Carbonate	Hardness
					pH units	uS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg CaCO3/L	mg CaCO3/L	mg HCO3/L	mg CO3/L	mg CaCO3/L
19-19847	MDPZ7450C	16/11/2019	Hydrasleeve	20	7.6	900	600	32	22	120	10	<0.1	<0.01	<0.01	150	39	0.05	53	<0.02	1.1	240	240		<5	170
19-19847	MDPZ7451A	16/11/2019	Hydrasleeve	105	6.9	23000	17000	310	680	4500	280	<0.1	0.02	2.2	6800	3000	0.02	22	<0.02	<0.01	330	330		<5	3600
19-19847	MDPZ7451B	16/11/2019	Hydrasleeve	60	7.2	15000	12000	260	360	2800	180	<0.1	<0.01	1.1	4400	2100	0.05	35	<0.02	0.2	390	390		<5	2100
19-19847	MDPZ7451C	16/11/2019	Hydrasleeve	20	7	2800	1800	76	71	350	53	<0.1	<0.01	<0.01	620	500	0.03	48	<0.02	5.8	190	190		<5	480
19-19847	MDPZ7452A	16/11/2019	Hydrasleeve	70	7.9	12000	8800	170	280	2100	210	<0.1	0.08	0.1	3300	1200	0.27	36	0.35	<0.01	690	690		<5	1600
19-19847	MDPZ7452B	16/11/2019	Hydrasleeve	45	7.4	7300	5000	110	150	1300	130	<0.1	<0.01	<0.01	1700	980	0.06	55	<0.02	5.2	390	390		<5	890
19-19847	MDPZ7452C	16/11/2019	Hydrasleeve	20	7.4	6800	4600	110	140	1100	110	<0.1	<0.01	<0.01	1600	940	0.06	61	<0.02	5.3	400	400		<5	850
19-19847	MDPZ7453A	16/11/2019	Hydrasleeve	65	7.1	20000	16000	330	510	3700	230	<0.1	<0.01	<0.01	5900	3700	0.07	51	<0.02	0.66	390	390		<5	2900
19-19847	MDPZ7453B	16/11/2019	Hydrasleeve	40	7.2	16000	13000	290	410	2800	180	<0.1	<0.01	<0.01	4300	2400	0.09	65	<0.02	3.1	370	370		<5	2400
19-19847	MDPZ7453C	16/11/2019	Hydrasleeve	10	7.2	15000	12000	320	480	2500	160	<0.1	<0.01	<0.01	4100	2200	0.09	71	<0.02	6.3	350	350		<5	2800
19-19847	MDPZ7455	17/11/2019	Hydrasleeve	50	3.6	1200	1000	58	36	43	35	4.4	23	0.41	100	450	0.03	68	0.29	<0.01	<5	<5		<5	290
19-19847	MDPZ7456A	17/11/2019	Hydrasleeve	105	7	3700	2500	84	110	490	49	<0.1	<0.01	1.6	940	300	0.02	27	0.24	0.15	280	280		<5	660
19-19847	MDPZ7456B	17/11/2019	Hydrasleeve	55	7	3700	2400	110	85	520	54	<0.1	<0.01	0.01	940	400	0.03	48	<0.02	5.1	160	160		<5	630
19-19847	MDPZ7456C	17/11/2019	Hydrasleeve	20	7.1	2800	2000	94	72	360	46	<0.1	<0.01	<0.01	720	330	0.05	53	<0.02	4.6	170	170		<5	530
19-19847	MDPZ7466 Lower	17/11/2019	Hydrasleeve	60	4.4	1400	1200	60	46	76	34	1.9	<0.01	1.3	140	480	0.03	59	<0.02	1.4	<5	<5		<5	340
19-19847	MDPZ7466 Upper	17/11/2019	Hydrasleeve	40	5.9	300	180	7.5	9.8	20	6.9	<0.1	0.03	<0.01	42	14	0.03	46	<0.02	4.7	36	36		<5	59
19-19847	MDPZ7467 Lower	17/11/2019	Hydrasleeve	62	4.4	670	1400	130	60	140	28	<0.1	0.05	0.79	180	380	0.02	20	0.18	<0.01	<5	<5		<5	570
19-19847	MDPZ7467 Upper	17/11/2019	Hydrasleeve	50	6.5	1300	880	82	45	110	24	<0.1	0.03	0.91	120	280	0.01	24	0.12	<0.01	180	180		<5	390
19-19847	MD5382	18/11/2019	Hydrasleeve	45	7	840	560	37	25	82	15	<0.1	0.02	0.01	94	100	0.04	52	<0.02	5.5	150	150		<5	200
19-19847	MD5455	18/11/2019	Hydrasleeve	68	6.8	1800	1500	70	64	330	38	<0.1	0.03	0.02	530	280	0.03	41	<0.02	4.8	240	240		<5	440
19-19847	MD5461	18/11/2019	Hydrasleeve	65	7.1	2900	1900	77	76	380	41	<0.1	0.01	<0.01	630	310	0.03	44	<0.02	5.7	230	230		<5	510
19-19847	MD6605 Lower	18/11/2019	Hydrasleeve	85	6.8	1800	1300	120	50	110	29	<0.1	<0.01	0.55	210	350	0.01	15	<0.02	<0.01	240	240		<5	510
19-19847	MD6605 Upper	18/11/2019	Hydrasleeve	55	6.7	1300	890	100	43	93	26	<0.1	<0.01	0.19	130	250	0.02	25	<0.02	0.78	180	180		<5	430
19-19847	MDPZ7450A	18/11/2019	Hydrasleeve	98	7	13000	10000	190	310	2600	170	<0.1	<0.01	0.17	3900	2200	0.02	16	<0.02	0.61	330	330		<5	1800
20-08048	MDPZ7449A	2/05/2020	Hydrasleeve	65	7.1	1800	1200	160	75	180	35				270	320	<0.01	12	0.27	<0.01	400	400		<5	710
20-08048	MDPZ7449B	2/05/2020	Hydrasleeve	25	7.2	1700	1100	91	60	180	34				370	250	0.04	46	<0.02	5.5	180	180		<5	470
20-08048	MDPZ7449C	2/05/2020	Hydrasleeve	9	6.7	7900	7200	600	400	790	97				2300	1600	0.09	65	<0.02	14	130	130		<5	3100
20-08048	MDPZ7450A	2/05/2020	Hydrasleeve	98	7.1	15000	11000	250	360	2700	310				4500	2400	0.02	14	0.03	0.21	370	370		<5	2100
20-08048	MDPZ7450B	2/05/2020	Hydrasleeve	35	7.6	1400	790	80	56	150	14				150	170	0.04	48	<0.02	5	320	320		<5	430
20-08048	MDPZ7450C	2/05/2020	Hydrasleeve	20	7.7	890	600	39	25	140	13				140	45	0.06	52	<0.02	1.1	260	260		<5	200
20-08048	MDPZ7451A	2/05/2020	Hydrasleeve	105	6.9	22000	18000	410	650	4300	540				7200	3700	0.04	21	<0.02	<0.01	360	360		<5	3700
20-08048	MDPZ7451B	2/05/2020	Hydrasleeve	60	7.2	15000	12000	340	390	2900	330				4700	2400	0.07	36	<0.02	0.56	410	410		<5	2500
20-08048	MDPZ7451C	2/05/2020	Hydrasleeve	20	7.2	2900	1800	99	80	390	62				640	400	0.06	48	<0.02	6.2	220	220		<5	580
20-08048	MDPZ7457A	2/05/2020	Hydrasleeve	90	6.8	14000	11000	250	340	2700	350				4200	2100	0.02	13	<0.02	0.32	420	420		<5	2000
20-08048	MDPZ7457B	2/05/2020	Hydrasleeve	45	7.3	9700	8000	250	230	1900	240				3000	1800	0.09	48	0.04	1.3	340	340		<5	1600
20-08048	MDPZ7457C	2/05/2020	Hydrasleeve	28	7.3	7200	4900	170	150	1100	140				1900	970	0.13	57	0.38	3	400	400		<5	1000
20-08048	MDPZ7458A	2/05/2020	Hydrasleeve	68	7.1	12000	9100	220	280	2300	280				4000	1700	0.07	31	<0.02	3.9	410	410		<5	1700
20-08048	MDPZ7458B	2/05/2020	Hydrasleeve	50	7.1	13000	10000	230	300	2800	310				4500	1900	0.09	41	0.15	3.7	430	430		<5	1800
20-08048	MDPZ7458C	2/05/2020	Hydrasleeve	8	7.6	1300	8700	140	270	2500	300				4000	1500	0.22	70	<0.02	4.5	570	570		<5	1500
20-08048	MDPZ7460A	2/05/2020	Hydrasleeve	85	7.2	6000	4000	140	130	880	110				1500	650	0.02	21	0.19	<0.01	320	320		<5	890
20-08048	MDPZ7460B	2/05/2020	Hydrasleeve	49	7.1	4400	2700	140	110	580	84				1100	510	0.05	44	0.04	4.6	210	210		<5	800
20-08048	MDPZ7460C	2/05/2020	Hydrasleeve	25	7.2	4300	2700	140	110	540	82				1100	490	0.06	48	<0.02	4.5	210	210		<5	800
20-08048	MDPZ7469A	2/05/2020	Hydrasleeve	100	6.4	14000	11000	230	400	2800	430				4400	2300	0.01	11	0.06	<0.01	300	300		<5	2200
20-08048	MDPZ7469B	2/05/2020	Hydrasleeve	75	7.1	3200	1900	100	91	380	82				720	390	0.04	44	<0.02	6.1	200	200		<5	620
20-08048	MDPZ7469C	2/05/2020	Hydrasleeve	35	7.4	2700	1700	94	84	330	77				580	340	0.05	46	<0.02	6.2	220	220		<5	580
20-08048	MDPZ7470A	2/05/2020	Hydrasleeve	90	7.1	8100	5700	170	200	1400	130				2300	880	0.05	41	0.08	2.3	370	370		<5	1200
20-08048	MDPZ7470B	2/05/2020	Hydrasleeve	45	7.3	6000	4100	110	120	980	180				1600	640	0.11	59	0.02	3.7	370	370		<5	770
20-08048	MDPZ7470C	2/05/2020	Hydrasleeve	20	7.5	6200	4000	120	130	950	190				1600	650	0.13	50	<0.02	3.1	360	360		<5	840
20-08048	MDPZ7452A	3/05/2020	Hydrasleeve	70	8	11000	9000	240	330	2200	250				4000	1400	0.17	35	0.24	<0.01	660	660		<5	2000
20-08048	MDPZ7452B	3/05/2020	Hydrasleeve	45	7.4	7500	5200	140	180	1300	140				1800	950	0.07	51	<0.02	5.4	430	430		<5	1100
20-08048	MDPZ7452C	3/05/2020	Hydrasleeve	20	7.6	6900	4700	140	150	1200	130				1700	890	0.12	58	<0.02	5.7	430	430		<5	970
20-08048	MDPZ7453A	3/05/2020	Hydrasleeve	65	7.2	20000	15000	440	550	3900	490				6200	3400	0.1	46	0.24	0.76	420	420		<5	3400
20-08048	MDPZ7453B	3/05/2020	Hydrasleeve	40	7.4	15000	12000	390	480	2700	360				4500	2800	0.12	71	<0.02	4.1	400	400		<5	3000
20-08048	MDPZ7453C	3/05/2020	Hydrasleeve	10	7.3	14000	12000	390	500	2500	340				4600	2600	0.11	75	0.02	3.5	390	390		<5	3000
20-08048	MDPZ7459	3/05/2020	Hydrasleeve	20	7.7	620	390	43	22	44	2				28	14	0.09	57	<0.02	1.3	270	270		<5	200
20-08048	MDPZ7462A	3/05/2020	Hydrasleeve	115	7.1	11000	8300	290	300	2000	250				3400	1500	0.03	23	0.89	0.08	440	440		<5	2000
20-08048	MDPZ7462B	3/05/2020	Hydrasleeve	55	7.4	4900	3100	130	140	660	85				1300	630	0.08	55	<0.02	5	350	350		<5	900
20-08048	MDPZ7462C	3/05/2020	Hydrasleeve	30	7.4	3500	2200	110	120	380	59				860	410	0.07	67	<0.02	9	280	280		<5	770
20-08048	MDPZ7464 Lower	3/05/2020	Hydrasleeve	85	7.1	1500	12000	270	450	2900	460				4900	2700	0.03	16	<0.02	0.21	350	350		<5	2500
20-08048	MDPZ7464 Upper	3/05/2020	Hydrasleeve	15	7.6	2000	1200	70	64	240	40				380	220	0.07	44	<0.02	2.1	380	380		<5	440
20-08048	MDPZ7468A	3/05/2020	Hydrasleeve	85	7	18000	15000	280	520	3500	530				5900	3200	0.03	17	0.17	<0.01	380	380		<5	2800
20-08048	MDPZ7468B	3/05/2020	Hydrasleeve	60	7.2	14000	11000	240	410	2700	420				4200	2400	0.06	37	<0.02	2.6	360	360		<5	2300
20-08048	MDPZ7468C	3/05/2020	Hydrasleeve	30	7.2	9800	7400	180	280	1700	290				2800	1600	0.05	39	<0.02	3.5	330	330		<5	1600
20-08048	MDPZ7471A	3/05/2020	Hydrasleeve	72	7.3	8500	5900	130	230	1300	230				2400	1100	0.09	47	<0.02	4.4	400	400		<5	1300
20-08048	MDPZ7471B	3/05/2020	Hydrasleeve	55	7.4	9100	6500	160	280	1500	220				2800	1200	0.08	47	<0.02	3.8	400	400		<5	1600
20-08048	MDPZ7471C	3/05/2020	Hydrasleeve	15	7.6	7400	4800	94	170	1100	150				1800	860	0.12	64	<0.02	5.2	460	460		<5	940
20-08048	MD5382	4/05/2020	Hydrasleeve	45	7	840	520	35	25	80	33				150	96	0.04	51	<0.02	5.1	160	160		<5	190
20-08048	MD5461	4/05/2020	Hydrasleeve	65	7.3	3100	1900	81	83	330	74				690	380	0.04	45	<0.02	4.9	240	240		<5	540
20-08048	MD6605 Lower	4/05/2020	Hydrasleeve	85	7	1800	1200	120	59	110	70				270	430	0.01	15	<0.02	<0.01	260	260		<5	540
20-08048	MD6605 Upper	4/05/2020	Hydrasleeve	55	6.9	1200	820	94	44	90	56				150	290	0.02	27	<0.02	0.71	190	190		<5	420
20-08048	MDPZ7454	4/05/2020	Hydrasleeve	50	6.5	770	520	26	21	63	27				100	150	0.02	30	0.03	1.5	83	83		<5	150
20-08048	MDPZ7455	4/05/2020	Hydrasleeve	50	3.7	1100	930	70	36	51	41				65	440	0.04	68	0.34	<0.01	<5	<5		<5	320
20-08048	MDPZ7456A	4/05/2020	Hydrasleeve	105	7.5	3400	2200	90	110	440	58				870	410	0.06	33	0.04	1.4	240	240		<5	680
20-08048	MDPZ7456B	4/05/2020	Hydrasleeve	55	7.5	3800	2400	130	93	470	64				960	440	0.05	48	<0.02	5.3	170	170		<5	710
20-08048	MDPZ7456C	4/05/2020	Hydrasleeve	20	7.1	3300	2100	110	87	400	70				800	420	0.09	66	<0.02	5.5	170	170		<5	630
20-08048	MDPZ7463 Lower	4/05/2020	Hydrasleeve	80	7.1	9500	7800	170	230	1600	200				2700	1700	0.05	39	0.03	2.9	350	350		<5	1400
20-08048	MDPZ7463 Upper	4/05/2020	Hydrasleeve	15	7.4	3900	2400	94	87	550	73				810	520	0.05	50	<0.02	3.5	390	390		<5	590
20-08048	MDPZ7466 Lower	4/05/2020	Hydrasleeve	60	3.9	1500	1100	91	64	94	70				130	540	0.04	57	<0.02	1	<5	<5		<5	490
20-08048	MDPZ7466 Upper	4/05/2020	Hydrasleeve	40	6	450	270	7.6	11	26	13				54	13	0.04	43	<0.02	5	44	44		<5	64
20-08048	MDPZ7467 Lower	4/05/2020	Hydrasleeve	62	6.9	1800	1200	170	76	160	59				170	460	0.02	20	0.16	<0.01	370	370		<5	740
20-08048	MDPZ7467 Upper	4/05/2020	Hydrasleeve	50	6.4	1300	860	90	51	110	42				130	350	0.02	23	0.23	<0.01	200	200		<5	440
20-08574	MDPZ7461	10/05/2020	Hydrasleeve	20	8.6		3300	150	160	930	110	0.02			1400	680	0.07	62	0.04	5.7	400	400		<5	1000
20-08574	MDPZ7465	10/05/2020	Hydrasleeve	90	6.9		1200	74	76	230	30	0.06			490	25	0.02	29	0.39	<0.01	420	420		<5	500
21-05186	MDPZ7455	16/03/2021	Hydrasleeve	50	3.5		970	72	40	51	43	9.6	4.1	0.71	71	420	0.02	65	0.29	0.03	<5	<5		<5	350
21-05186	MDPZ7456A	16/03/2021	Hydrasleeve	105	7.6		2500	97	71	480	64	0.01	<0.01	0.05	830	400	0.06	33	0.03	2.1	220	220		<5	540
21-05186	MDPZ7456B	16/03/2021	Hydrasleeve	55	7.2		2700	120	66	520	65	0.01	<0.01	<0.01	930	430	0.03	46	0.02	6	160	160		<5	570
21-05186	MDPZ7456C	16/03/2021	Hydrasleeve	20	7.1		2600	110	67	470	76	<0.01	<0.01	<0.01	840	450	0.04	65	0.02	7.3	160	160		<5	550
21-05186	MDPZ7464 Lower	16/03/2021	Hydrasleeve	85	7		12000	290	470	2900	450	<0.01	<0.01	<0.01	4800	2300	0.01	16	<0.02	0.29	340	340		<5	2700
21-05186	MDPZ7464 Upper	16/03/2021	Hydrasleeve	15	7.2		1300	76	58	270	34	0.03	0.01	<0.01	380	250	0.02	43	<0.02	2.6	370	370		<5	430
21-05186	MDPZ7466 Lower	16/03/2021	Hydrasleeve	60	3.9		1200	87	59	90	50	3.2	0.01	1.8	150	520	0.02	58	0.04	0.8	<5	<5		<5	460
21-05186	MDPZ7466 Upper	16/03/2021	Hydrasleeve	40	5.9		190	7.7	9.4	32	9.3	0.04	0.02	<0.01	37	14	0.02	45	<0.02	5.7	41	41		<5	58
21-05186	MDPZ7467 Lower	16/03/2021	Hydrasleeve	62	6.9		1300	160	53	110	37	<0.01	<0.01	0.85	140	450	<0.01	19	0.17	0.03	390	390		<5	620
21-05186	MDPZ7467 Upper	16/03/2021	Hydrasleeve	50	6.6		940	98	39	92	33	0.01	<0.01	1.1	170	330	<0.01	22	0.17	0.01	190	190		<5	410
21-05186	MDPZ7469A	16/03/2021	Hydrasleeve	100	6.4		11000	250	420	3000	350	0.03	0.02	4.6	4700	2100	<0.01	12	0.07	0.02	280	280		<5	1500
21-05186	MDPZ7469B	16/03/2021	Hydrasleeve	75	7.1		1900	100	63	430	61	<0.01	<0.01	<0.01	720	370	0.02	48	<0.02	6.6	190	190		<5	510
21-05186	MDPZ7469C	16/03/2021	Hydrasleeve	35	7.2		1700	99	60	360	56	0.01	<0.01	<0.01	600	320	0.04	47	<0.02	6.9	210	210		<5	490
21-05186	MDPZ7449A	17/03/2021	Hydrasleeve	65	7.1		1200	130	52	120	40	0.01	<0.01	0.22	220	300	<0.01	12	0.03	0.01	400	400		<5	540
21-05186	MDPZ7449B	17/03/2021	Hydrasleeve	25	7		1100	78	43	200	38	0.01	<0.01	<0.01	340	240	0.02	47	<0.02	6.4	160	160		<5	370

Lab Report	Bore ID	Sample Date	Sample Type	Sample Depth	pH	Conductivity	Total Dissolved Solids	Calcium - Dissolved	Magnesium - Dissolved	Sodium - Dissolved	Potassium - Dissolved	Aluminium - Dissolved	Iron - Dissolved	Manganese - Dissolved	Chloride	Sulfate	Filterable Reactive Phosphorus	Reactive Silica	Ammonia-N	Nitrate-N	Total Alkalinity	Bicarbonate	Bicarbonate	Carbonate	Hardness
					pH units	uS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg CaCO3/L	mg CaCO3/L	mg HCO3/L	mg CO3/L	mg CaCO3/L
21-05186	MDPZ7449C	17/03/2021	Hydrasleeve	9	6.9		6300	430	180	610	110	<0.01	<0.01	<0.01	1700	1200	0.06	69	0.02	13	140	140		<5	1800
21-05186	MDPZ7450A	17/03/2021	Hydrasleeve	98	7		14000	230	430	3400	450	<0.01	0.01	0.14	5000	2600	<0.01	12	0.08	0.03	380	380		<5	1400
21-05186	MDPZ7450B	17/03/2021	Hydrasleeve	35	7.2		830	68	37	140	15	0.04	0.02	<0.01	170	150	0.02	48	<0.02	5.3	310	310		<5	320
21-05186	MDPZ7450C	17/03/2021	Hydrasleeve	20	7.4		550	31	17	130	14	0.03	<0.01	<0.01	150	45	0.02	52	<0.02	1.2	220	220		<5	150
21-05186	MDPZ7454	17/03/2021	Hydrasleeve	50	6.5		380	21	14	63	27	0.06	0.02	<0.01	78	120	<0.01	30	<0.02	1.5	93	93		<5	110
21-05186	MDPZ7459	17/03/2021	Hydrasleeve	20	7.6		330	40	16	36	2	0.01	<0.01	<0.01	28	14	0.07	57	<0.02	1.4	250	250		<5	170
21-05186	MDPZ7460A	17/03/2021	Hydrasleeve	85	7.2		4000	130	85	940	110	<0.01	0.02	0.28	1700	690	<0.01	20	0.44	<0.01	300	300		<5	680
21-05186	MDPZ7460B	17/03/2021	Hydrasleeve	49	7		3100	150	100	700	81	<0.01	<0.01	<0.01	1100	540	0.03	48	0.03	4.8	190	190		<5	790
21-05186	MDPZ7460C	17/03/2021	Hydrasleeve	25	7		3000	140	97	590	79	0.02	<0.01	<0.01	1100	210	0.03	49	0.03	5.5	190	190		<5	750
21-05186	MDPZ7463 Lower	17/03/2021	Hydrasleeve	80	7.1		7500	180	230	1400	140	0.01	0.01	<0.01	2600	1400	0.03	39	0.02	3.2	340	340		<5	1400
21-05186	MDPZ7463 Upper	17/03/2021	Hydrasleeve	15	7.2		2600	100	79	590	65	0.01	<0.01	<0.01	840	530	0.03	50	<0.02	3.9	380	380		<5	580
21-14674	MDPZ7451A	4/08/2021	Hydrasleeve	105	6.9		18000	360	650	5000	680	<0.01	<0.01	2.5	5900	4200	0.03	25	<0.02	<0.01	340	340		<5	3600
21-14674	MDPZ7451B	4/08/2021	Hydrasleeve	60	7.2		11000	280	210	3100	390	0.01	0.01	0.05	4600	2400	0.07	47	<0.02	2.4	410	410		<5	1600
21-14674	MDPZ7451C	4/08/2021	Hydrasleeve	20	7.3		2100	83	68	440	68	0.01	0.01	<0.01	690	420	0.05	54	<0.02	12	200	200		<5	490
21-14674	MDPZ7452A	4/08/2021	Hydrasleeve	70	7.8		9700	200	190	2400	300	<0.01	0.09	0.18	4000	1400	0.28	38	0.22	<0.01	580	580		<5	1300
21-14674	MDPZ7452B	4/08/2021	Hydrasleeve	45	7.4		5000	120	120	1300	160	<0.01	0.01	<0.01	1900	840	0.15	62	0.05	8.1	480	480		<5	790
21-14674	MDPZ7452C	4/08/2021	Hydrasleeve	20	7.4		4500	110	110	1200	140	<0.01	<0.01	<0.01	1700	790	0.07	66	<0.02	6.7	420	420		<5	730
21-14674	MDPZ7453A	4/08/2021	Hydrasleeve	65	7.1		16000	340	510	4500	600	<0.01	<0.01	0.01	5700	3500	0.09	56	0.1	0.9	430	430		<5	2900
21-14674	MDPZ7453B	4/08/2021	Hydrasleeve	40	7.3		13000	300	470	3000	400	<0.01	<0.01	<0.01	4300	3000	0.09	84	<0.02	5.5	390	390		<5	2700
21-14674	MDPZ7453C	4/08/2021	Hydrasleeve	10	7.3		13000	290	490	2800	400	<0.01	<0.01	<0.01	5200	2700	0.12	86	<0.02	8.2	370	370		<5	2700
21-14674	MDPZ7457A	4/08/2021	Hydrasleeve	90	7		11000	210	190	2900	380	<0.01	<0.01	0.86	5100	2200	0.02	17	0.03	0.39	410	410		<5	1300
21-14674	MDPZ7457B	4/08/2021	Hydrasleeve	45	7.4		8400	200	150	2200	260	<0.01	<0.01	0.02	3500	1800	0.1	57	0.02	1.3	280	280		<5	1100
21-14674	MDPZ7457C	4/08/2021	Hydrasleeve	28	7.4		5200	130	110	1300	160	<0.01	0.03	0.02	1900	900	0.1	67	<0.02	4.5	390	390		<5	780
21-14674	MDPZ7458A	5/08/2021	Hydrasleeve	68	7.2		9800	180	170	2400	300	<0.01	0.01	0.06	3900	1700	0.05	42	<0.02	4.5	420	420		<5	1200
21-14674	MDPZ7458B	5/08/2021	Hydrasleeve	50	7.3		11000	190	180	2800	340	<0.01	<0.01	<0.01	4800	1800	0.06	49	<0.02	4.2	340	340		<5	1200
21-14674	MDPZ7458C	5/08/2021	Hydrasleeve	8	7.8		9100	150	160	2500	310	<0.01	<0.01	<0.01	3800	1300	0.77	80	<0.02	5.7	610	610		<5	1000
21-14674	MDPZ7461	5/08/2021	Hydrasleeve	20	7.4		4400	110	110	1100	130	<0.01	<0.01	<0.01	1800	560	0.08	66	0.07	6.5	350	350		<5	730
21-14674	MDPZ7468A	5/08/2021	Hydrasleeve	85	6.9		16000	250	500	3900	570	<0.01	0.04	1.4	5100	3200	0.02	16	0.14	<0.01	370	370		<5	2700
21-14674	MDPZ7468B	5/08/2021	Hydrasleeve	60	7.1		11000	210	190	3000	380	0.21	0.03	<0.01	4700	2400	0.05	44	<0.02	2.3	350	350		<5	1300
21-14674	MDPZ7468C	5/08/2021	Hydrasleeve	30	7.1		7300	140	150	1700	220	0.06	0.04	<0.01	2800	1500	0.03	45	<0.02	4.3	340	340		<5	970
21-14674	MDPZ7470A	5/08/2021	Hydrasleeve	90	7.2		6000	140	120	1500	170	<0.01	0.01	0.92	2600	800	0.04	48	0.09	2.5	340	340		<5	840
21-14674	MDPZ7470B	5/08/2021	Hydrasleeve	45	7.4		4100	99	87	1100	140	<0.01	<0.01	<0.01	1800	540	0.17	66	0.02	4.6	350	350		<5	610
21-14674	MDPZ7470C	5/08/2021	Hydrasleeve	20	7.5		4100	98	86	1100	150	0.04	0.03	<0.01	2000	520	0.14	72	0.02	4.6	340	340		<5	600
21-14674	MDPZ7471A	5/08/2021	Hydrasleeve	72	7.4		6200	120	140	1500	170	0.01	0.01	<0.01	2400	1100	0.08	55	0.08	5.2	420	420		<5	880
21-14674	MDPZ7471B	5/08/2021	Hydrasleeve	55	7.4		7000	140	160	1600	170	0.02	0.02	<0.01	3000	1200	0.06	55	<0.02	4.5	370	370		<5	1000
21-14674	MDPZ7471C	5/08/2021	Hydrasleeve	15	7.5		4500	81	110	1300	120	<0.01	<0.01	<0.01	2000	740	0.09	73	<0.02	6.4	470	470		<5	660
PE153340	MDPZ9201	9/07/2021	Airlift		8.1	2000	1300	110	70	170	37	<0.005	0.006	0.68	280	380		29		8.4	220		270	<1	560
PE153340	MDPZ9202	13/07/2021	Airlift		7.9	1200	860	69	45	100	36	<0.005	0.005	0.16	99	340		41		32	110		130	<1	360
PE153749	MDPZ9203	31/07/2021	Airlift		8.2	1100	790	74	50	89	22	<0.005	0.009	0.079				52		8.7					390
PE153634	MDPZ9204	20/07/2021	Airlift		8	2900	1700	92	76	350	42	<0.005	<0.005	0.025				54		23	160		200	<5	540
PE153749	MDPZ9205	24/07/2021	Airlift		7.9	1600	1000	67	49	170	27	<0.005	<0.005	0.007				47		20					370
PE153749	MDPZ9206	28/07/2021	Airlift		7.1	1700	1200	100	72	120	55	<0.005	3	1.1				17		3.7					550
PE154009	MDPZ9207	3/08/2021	Airlift		7.8	950	630	65	39	59	24	<0.005	<0.005	0.056				42		4.1					320
PE154009	MDPZ9208	7/08/2021	Airlift		7.8	1500	920	54	45	160	25	<0.005	<0.005	0.005				66		20					320
PE154009	MDPZ9209	11/08/2021	Airlift		7.7	490	320	22	18	39	7.6	<0.005	<0.005	<0.005				70		29					130
PE154235	MDPZ9210	15/08/2021	Airlift		8	4000	2400	71	78	580	60	<0.005	<0.005	0.076	890	550		33		16	230		280	<5	500
PE154462	MDPB0016	23/08/2021	Airlift		8.3	3100	2000	91	78	390	48	<0.005	<0.005	0.02				60		23					550
PE154462	MDPB0017	23/08/2021	Airlift		8.3	3000	1900	100	76	350	43	<0.005	<0.005	0.033				52		17					560
PE154462	MDPB0018	4/09/2021	Airlift		7.7	1300	880	75	50	100	44	<0.005	0.006	0.33	110	400		30		21	95		120	<5	390
PE155018	MDPB0019	10/09/2021	Airlift		8	910	560	60	35	51	24	<0.005	<0.005	0.13				41		4.8					300
PE155073	MDPZ9211	17/09/2021	Airlift		7.8	16000	9400	210	330	2600	270	<0.025	<0.025	0.53	4000	1900		34		11	390		470	<5	1900
PE155073	MDPZ9212	24/09/2021	Airlift		8	18000	11000	210	400	3000	300	<0.025	<0.025	0.17	4800	2200		44		9.8	400		480	<5	2200
PE155297	MDPZ9213	1/10/2021	Airlift		8	3100	1900	73	81	440	42	<0.005	<0.005	0.039				61		22					510
PE155297	MDPB0018	30/09/2021	Pumping Test - End		6.8	940	630	46	32	83	35	<0.005	0.11	0.14				44		27					250
PE155569	MDPZ9214	10/10/2021	Airlift		7.9	5800	3600	90	140	900	81	<0.005	<0.005	0.056	1300	730		74		21	400		480	<5	810
PE155569	MDPB0019	8/10/2021	Pumping Test		7	750	490	45	29	49	19	<0.005	<0.005	0.026	66	100		50		7.1	170		210	<5	230
PE155569	MDPB0017	13/10/2021	Pumping Test		7.3	2900	1900	93	72	340	42	<0.005	<0.005	0.01	620	360		59		21	160		200	<5	530
PE155734	MDPZ9215D	8/10/2021	Airlift		7.7	20000	14000	310	590	3300	360	<0.025	<0.025	2.2				26		2.4					3200
PE155887	MDPZ9215S	27/10/2021	Airlift		8.2	4300	2500	86	110	600	62	<0.005	<0.005	0.009	890	570		61		25	350		430	<1	670
PE155887	MDPZ9216	24/10/2021	Airlift		7.9	20000	14000	330	620	3400	340	<0.025	<0.025	2.6	5700	3300		24		1.3	360		440	<1	3400
PE156870	MDPB0020	12/11/2021	Airlift		7.9	18000	11000	210	420	3000	280	<0.025	<0.025	0.11				42		9.2					2300
PE156870	MDPZ9217	20/11/2021	Airlift		7.8	11000	7100	200	310	1600	160	<0.025	<0.025	0.083				37		12					1800
PE156870	MDPZ9218	26/11/2021	Airlift		7.8	8000	5100	170	250	1100	98	<0.01	<0.01	0.84				23		1.2					1500
PE157040	MDPZ9219	30/11/2021	Airlift		8	3800	2300	99	100	410	40	<0.005	<0.005	0.005	810	440		54		10	310		380	<5	680
PE157040	MDPZ9220	6/12/2021	Airlift		8.1	2700	1600	89	89	310	34	<0.005	0.093	0.028	540	320		36		3.3	260		320	<5	590
PE157322	MDPZ9221	12/12/2021	Airlift		8.1	3900	2400	110	130	440	44	<0.005	<0.005	0.009				58		16					810
21-19363	MDPZ7449A	16/10/2021	Hydrasleeve	65	7.3		1100	130	69	140	39	0.16	0.05	0.22	210	320	<0.01	16	<0.02	0.03	400	400		<5	610
21-19363	MDPZ7449B	16/10/2021	Hydrasleeve	25	6.9		1100	74	57	170	39	0.01	<0.01	<0.01	380	260	0.03	58	<0.02	6.3	170	170		<5	420
21-19363	MDPZ7449C	16/10/2021	Hydrasleeve	9	6.9		5000	320	200	570	91	0.04	0.03	<0.01	1300	1100	0.08	80	<0.02	13	160	160		<5	1600
21-19363	MDPZ7450A	16/10/2021	Hydrasleeve	98	7.3		7300	160	210	2000	200	0.03	0.02	0.08	2900	1600	0.02	29	<0.02	1.5	350	350		<5	1300
21-19363	MDPZ7450B	16/10/2021	Hydrasleeve	35	7.5		1100	63	49	110	16	0.08	0.05	<0.01	160	160	0.04	56	<0.02	4.5	340	340		<5	360
21-19363	MDPZ7450C	16/10/2021	Hydrasleeve	20	3.9		880	50	47	86	52	0.31	7.5	2	200	370	<0.01	30	0.7	0.61	<5	<5		<5	320
21-19363	MDPZ7454	16/10/2021	Hydrasleeve	50	7.5		590	31	24	110	15	0.06	0.04	<0.01	150	41	0.04	61	<0.02	1.3	240	240		<5	180
21-19363	MDPZ7455	16/10/2021	Hydrasleeve	50	3.4		860	63	38	45	47	6.4	29	0.44	80	440	0.04	77	0.27	<0.01	<5	<5		<5	310
PE157146	MDPB0016	30/11/2021	Pumping Test (Layflat)		7.6	3100	1900	96	78	380	49	0.014	0.024	0.005	690	400	0.45	62		<0.2	200		240	<5	560
PE157146	MDPB0020	5/12/2021	Pumping Test		7.7	17000	11000	130	250	1900	170	<0.025	<0.025	0.019	4500	2300	0.01	54		12	380		460	<5	1400
PE157146	MDPB0020	9/12/2021	Pumping Test		7.6	17000	11000	210	380	2800	270	<0.025	<0.025	0.024	4600	2300	<0.01	52		13	390		470	<5	2100
PE157146	MDPZ7449A	7/12/2021	Hydrasleeve	65	7.7	1900	1200	130	68	160	33	<0.005	<0.005	0.22	220	330	<0.01	16		0.3	390		480	<5	620
PE157146	MDPZ7449B	7/12/2021	Hydrasleeve	25	7.5	1800	1100	76	55	190	31	<0.005	<0.005	<0.001	310	270	<0.01	64		26	160		200	<5	420
PE157146	MDPZ7449C	7/12/2021	Hydrasleeve	9	7.6	5000	3500	260	190	480	64	<0.005	<0.005	<0.001	1100	940	0.09	91		48	160		190	<5	1400
PE157146	MDPZ7450A	7/12/2021	Hydrasleeve	98	7.7	10000	6500	150	220	1600	170	<0.01	<0.01	0.14	2600	1600	<0.01	31		7.4	330		400	<5	1300
PE157146	MDPZ7450B	7/12/2021	Hydrasleeve	35	7.8	1300	810	66	48	140	13	<0.005	<0.005	<0.001	160	150	<0.01	60		18	310		380	<5	360
PE157146	MDPZ7450C	7/12/2021	Hydrasleeve	20	8	880	520	36	25	110	11	<0.005	<0.005	<0.001	120	40	0.07	69		4.9	240		300	<5	190
PE157146	MDPZ7451A	5/12/2021	Hydrasleeve	105	7.5	22000	16000	310	580	4000	410	<0.025	<0.025	2.5	6400	3500	<0.01	29		<0.2	350		420	<5	3100
PE157146	MDPZ7451B	5/12/2021	Hydrasleeve	60	7.7	16000	11000	270	370	2800	270	<0.025	<0.025	0.026	4200	2500	0.04	51		6.1	380		470	<5	2200
PE157146	MDPZ7451C	5/12/2021	Hydrasleeve	20	7.6	3000	1800	88	79	400	57	<0.005	<0.005	<0.001	630	390	0.03	60		26	200		250	<5	550
PE157146	MDPZ7452A	5/12/2021	Hydrasleeve	70	7.9	13000	8000	190	300	2100	210	<0.025	<0.025	0.25	3300	1500	0.37	46		0.4	540		660	<5	1700
PE157146	MDPZ7452B	5/12/2021	Hydrasleeve	45	7.9	7600	4600	120	160	1200	120	<0.01	<0.01	<0.002	1800	970	<0.01	69		24	390		480	<5	950
PE157146	MDPZ7452C	5/12/2021	Hydrasleeve	20	7.9	6800	4100	110	140	1100	110	<0.01	<0.01	<0.002	1600	900	<0.01	73		25	410		500	<5	860
PE157146	MDPZ7453A	5/12/2021	Hydrasleeve	65	7.7	21000	14000	350	530	3700	380	<0.025	<0.025	0.006	5900	3500	0.09	62		5	410		500	<5	3000
PE157146	MDPZ7453B	5/12/2021	Hydrasleeve	40	7.8	16000	11000	330	490	2600	290	<0.025	<0.025	<0.005	4000	2800	<0.01	91		22	370		460	<5	2800
PE157146	MDPZ7453C	5/12/2021	Hydrasleeve	10	7.9	16000	11000	320	510	2500	280	<0.025	<0.025	<0.005	4200	2700	0.04	93		21	360		440	<5	2900
PE157146	MDPZ7454	9/12/2021	Hydrasleeve	50	5.5	1200	790	50	44	100	43	0.27	<0.005	2.4	180	330	<0.01	28		2.7	5		7	<5	300
PE157146	MDPZ7455	8/12/2021	Hydrasleeve	50	3.3	1200	790	69	38	50	41	5.9	24	0.37	82	440	<0.01	71		<0.2	<5		<5	<5	330
PE157146	MDPZ7456A	7/12/2021	Hydrasleeve	105	8	3600	2200	99	110	480	55	<0.005	0.026	<0.001	840	420	0.17	44		11	220		270	<5	690
PE157146	MDPZ7456B	7/12/2021	Hydrasleeve	55	7.6	3900	2500	120	99	530	53	<0.005	<0.005	<0.001	950	450	<0.01	59		24	160		200	<5	720
PE157146	MDPZ7456C	7/12/2021	Hydrasleeve	20	7.7	3100	2000	100	87	400	55	<0.005	<0.005	<0.001	700	410	0.02	77		26	160		200	<5	620
PE157146	MDPZ7457A	2/12/2021	Hydrasleeve	90	7.6	16000	9800	220	350	2700	270	<0.025	<0.025	0.75	4100	2300	<0.01	18		1.8	400		490	<5	2000

Lab Report	Bore ID	Sample Date	Sample Type	Sample Depth	pH	Conductivity	Total Dissolved Solids	Calcium - Dissolved	Magnesium - Dissolved	Sodium - Dissolved	Potassium - Dissolved	Aluminium - Dissolved	Iron - Dissolved	Manganese - Dissolved	Chloride	Sulfate	Filterable Reactive Phosphorus	Reactive Silica	Ammonia-N	Nitrate-N	Total Alkalinity	Bicarbonate	Bicarbonate	Carbonate	Hardness
					pH units	uS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg CaCO3/L	mg CaCO3/L	mg HCO3/L	mg CO3/L	mg CaCO3/L
PE157146	MDPZ7457B	2/12/2021	Hydrasleeve	45	7.8	12000	7500	210	220	1900	180	<0.025	<0.025	0.038	2900	1800	0.07	61		5.6	300		360	<5	1500
PE157146	MDPZ7457C	2/12/2021	Hydrasleeve	28	7.9	7400	4500	140	140	1200	120	<0.005	<0.005	0.005	1800	970	0.17	74		17	370		450	<5	940
PE157146	MDPZ7458A	4/12/2021	Hydrasleeve	68	7.8	14000	8900	210	290	2100	210	<0.025	<0.025	0.13	3600	1700	<0.01	44		17	410		490	<5	1700
PE157146	MDPZ7458B	4/12/2021	Hydrasleeve	50	7.9	14000	9100	190	280	2400	230	<0.025	<0.025	0.032	3900	1800	0.06	53		14	420		510	<5	1600
PE157146	MDPZ7458C	5/12/2021	Hydrasleeve	8	8.1	13000	8300	100	230	2200	220	<0.025	<0.025	<0.005	3500	1500	0.2	87		19	520		640	<5	1200
PE157146	MDPZ7459	6/12/2021	Hydrasleeve	20	8	600	390	43	22	45	1.9	<0.005	<0.005	<0.001	43	12	0.17	75		5.6	230		280	<5	200
PE157146	MDPZ7460A	7/12/2021	Hydrasleeve	85	7.9	6200	3800	120	130	920	88	<0.005	<0.005	0.29	1600	710	<0.01	28		1	290		350	<5	830
PE157146	MDPZ7460B	7/12/2021	Hydrasleeve	49	7.8	4600	2900	130	110	610	64	<0.005	<0.005	0.018	1100	500	<0.01	59		22	210		250	<5	770
PE157146	MDPZ7460C	7/12/2021	Hydrasleeve	25	7.8	4400	2700	130	110	600	65	<0.005	<0.005	<0.001	1100	490	0.03	63		21	190		230	<5	780
PE157146	MDPZ7461	5/12/2021	Hydrasleeve	20	8	6400	3800	110	140	940	91	<0.005	<0.005	0.002	1600	750	<0.01	71		28	360		440	<5	860
PE157146	MDPZ7463 Lower	1/12/2021	Hydrasleeve	80	7.7	7200	4500	140	170	1100	100	<0.025	<0.025	<0.005	1700	1100	<0.01	55		14	340		420	<5	1100
PE157146	MDPZ7463 Upper	1/12/2021	Hydrasleeve	15	7.8	4000	2400	86	83	560	51	<0.005	<0.005	0.002	800	580	<0.01	63		15	360		440	<5	560
PE157146	MDPZ7464 Lower	6/12/2021	Hydrasleeve	85	7.6	13000	8300	170	290	2000	220	<0.025	<0.025	0.026	3200	1900	0.02	31		3.3	330		410	<5	1600
PE157146	MDPZ7464 Upper	6/12/2021	Hydrasleeve	15	7.9	1900	1100	59	52	230	25	<0.005	<0.005	<0.001	290	210	0.05	58		8.6	340		420	<5	360
PE157146	MDPZ7466 Lower	8/12/2021	Hydrasleeve	60	4.5	1400	1000	75	53	95	44	3.6	0.008	1.9	140	480	<0.01	72		7.2	<5		<5	<5	400
PE157146	MDPZ7466 Upper	8/12/2021	Hydrasleeve	40	6.7	320	230	8	9.5	24	8.2	<0.005	<0.005	0.002	50	15	<0.01	58		23	40		49	<5	59
PE157146	MDPZ7467 Lower	8/12/2021	Hydrasleeve	62	7.3	1900	1300	150	64	150	30	<0.005	<0.005	0.91	160	460	<0.01	26		<0.2	360		440	<5	640
PE157146	MDPZ7467 Upper	8/12/2021	Hydrasleeve	50	7	1400	1100	86	43	120	26	<0.005	<0.005	0.98	130	360	0.02	27		0.2	190		240	<5	390
PE157146	MDPZ7468A	1/12/2021	Hydrasleeve	85	7.7	21000	15000	260	490	3500	380	<0.025	<0.025	0.86	5900	3300	8.8	20		<0.2	370		450	<5	2700
PE157146	MDPZ7468B	1/12/2021	Hydrasleeve	60	7.8	15000	10000	210	350	2500	260	<0.025	<0.025	0.007	4000	2400	<0.01	49		9.2	350		430	<5	2000
PE157146	MDPZ7468C	1/12/2021	Hydrasleeve	30	7.8	10000	6500	150	220	1600	170	<0.01	<0.01	<0.002	2500	1600	<0.01	51		17	300		370	<5	1300
PE157146	MDPZ7470A	1/12/2021	Hydrasleeve	90	7.9	8600	5200	150	170	1200	120	<0.01	<0.01	0.92	2200	930	0.1	51		8.9	310		380	<5	1100
PE157146	MDPZ7470B	1/12/2021	Hydrasleeve	45	7.9	6200	3800	100	100	940	100	<0.005	<0.005	<0.001	1500	710	0.37	78		16	330		410	<5	680
PE157146	MDPZ7470C	1/12/2021	Hydrasleeve	20	8.1	6200	3600	99	97	900	120	<0.005	0.009	0.012	1500	630	1.7	78		11	460		570	<5	650
PE157146	MDPZ7471A	6/12/2021	Hydrasleeve	72	7.9	8900	5600	120	200	1400	130	<0.01	<0.01	0.004	2200	1200	<0.01	64		21	390		480	<5	1100
PE157146	MDPZ7471B	6/12/2021	Hydrasleeve	55	8	9500	6000	140	220	1500	130	<0.01	<0.01	<0.002	2400	1300	<0.01	61		19	390		470	<5	1300
PE157146	MDPZ7471C	6/12/2021	Hydrasleeve	15	8.1	7100	4400	86	140	1200	86	<0.01	<0.01	<0.002	1700	910	0.1	81		25	440		540	<5	790
PE157321	MD5382	12/12/2021	Hydrasleeve	45	7.8	830	500	34	22	89	15	<0.005	<0.005	0.006	110	99	0.02	63		27	140		180	<5	180
PE157321	MD5461	12/12/2021	Hydrasleeve	50	8	2900	1700	79	77	360	39	<0.005	<0.005	0.002	590	360	<0.01	59		35	230		280	<5	520
PE157321	MD6605 Lower	12/12/2021	Hydrasleeve	85	7.9	1700	1100	140	61	130	33	<0.005	0.023	2.5	190	400	0.01	24		1.7	210		260	<5	590
PE157321	MD6605 Upper	12/12/2021	Hydrasleeve	55	7.7	1300	870	100	42	100	27	<0.005	0.027	0.006	150	300	<0.01	33		5.7	180		220	<5	430
PE157321	MDPZ9205	15/12/2021	Hydrasleeve	35	7.5	2100	1200	79	59	230	30	<0.005	<0.005	0.002	420	300	<0.01	54		26	140		170	<5	440
PE157321	MDPZ9211	16/12/2021	Hydrasleeve	48	7.9	12000	7300	170	260	1900	180	<0.025	<0.025	<0.005	3100	1400	<0.01	55		24	390		480	<5	1500
PE157321	MDPZ9212D	16/12/2021	Hydrasleeve	105	7.8	18000	12000	230	420	3000	290	<0.025	<0.025	0.12	4700	2400	<0.01	43		8.4	390		470	<5	2300
PE157321	MDPZ9212S	16/12/2021	Hydrasleeve	20	8	17000	10000	150	360	2800	270	<0.025	<0.025	<0.005	4200	1900	0.02	79		15	410		500	<5	1900
PE157321	MDPZ9213	13/12/2021	Hydrasleeve	40	7.9	2100	1300	90	98	180	22	<0.005	<0.005	<0.001	370	270	<0.01	63		30	350		430	<5	630
PE157321	MDPZ9214	15/12/2021	Hydrasleeve	40	8	5200	3000	76	120	770	64	<0.005	<0.005	0.001	1100	650	<0.01	75		25	390		470	<5	680
PE157321	MDPZ9215D	15/12/2021	Hydrasleeve	80	7.9	11000	6600	140	260	1600	150	<0.025	<0.025	0.026	2700	1500	<0.01	48		17	370		450	<5	1400
PE157321	MDPZ9215S	15/12/2021	Hydrasleeve	20	8	5500	3100	96	130	760	71	<0.005	<0.005	<0.001	1300	750	<0.01	52		24	340		410	<5	780
PE157321	MDPZ9216	15/12/2021	Hydrasleeve	90	7.6	20000	13000	330	620	3200	320	<0.025	<0.025	0.97	5500	3200	<0.01	25		1.4	330		410	<5	3400
PE157321	MDPZ9217	13/12/2021	Hydrasleeve	30	7.7	8100	5000	170	240	1100	96	<0.01	<0.01	0.002	1900	1100	<0.01	49		19	300		360	<5	1400
PE157321	MDPZ9218	13/12/2021	Hydrasleeve	30	7.7	7500	4600	160	230	1000	89	<0.01	<0.01	1.3	1800	960	<0.01	26		2.5	280		340	<5	1400
PE157321	MDPZ9219	13/12/2021	Hydrasleeve	30	7.8	3900	2300	110	120	450	43	<0.005	<0.005	0.001	860	450	<0.01	53		12	270		340	<5	760
PE157321	MDPZ9220	13/12/2021	Hydrasleeve	30	7.9	2500	1400	82	89	290	34	<0.005	<0.005	0.03	630	300	<0.01	28		2.2	270		330	<5	570
PE157321	MDPZ9221	14/12/2021	Hydrasleeve	30	7.9	3800	2300	110	130	440	44	<0.005	<0.005	0.008	910	460	0.01	63		18	300		370	<5	790
PE161850	MD5382	5/07/2022	Hydrasleeve	45	7.4	840	530	33	22	77	16	<0.005	<0.005	<0.001	100	98		69		25	150		180	<5	170
PE161850	MD5461	5/07/2022	Hydrasleeve	65	7.6	2900	1800	73	69	330	39	<0.005	<0.005	<0.001	590	360		63		32	240		290	<5	470
PE161850	MDPZ7449A	6/07/2022	Hydrasleeve	65	7.6	2000	1200	120	64	140	30	<0.005	0.015	0.28	240	340		18		0.3	400		480	<5	560
PE161850	MDPZ7449B	6/07/2022	Hydrasleeve	25	7.5	1800	1100	70	52	160	29	<0.005	<0.005	<0.001	310	270		69		27	170		210	<5	390
PE161850	MDPZ7449C	6/07/2022	Hydrasleeve	9	7.5	5100	3300	270	200	500	67	<0.005	<0.005	<0.001	1100	920		99		51	160		200	<5	1500
PE161850	MDPZ7450A	6/07/2022	Hydrasleeve	98	7.6	15000	9900	180	330	2700	270	<0.025	0.22	0.3	3800	2300		21		1.9	370		450	<5	1800
PE161850	MDPZ7450B	6/07/2022	Hydrasleeve	35	7.7	1300	840	59	45	120	12	<0.005	<0.005	0.004	200	170		66		20	330		400	<5	330
PE161850	MDPZ7450C	6/07/2022	Hydrasleeve	20	7.9	990	590	33	23	100	11	<0.005	<0.005	<0.001	150	42		74		6.5	240		300	<5	180
PE161850	MDPZ7451A	6/07/2022	Hydrasleeve	105	7.5	23000	16000	300	580	4300	460	<0.025	<0.025	2.9	6700	3600		28		0.3	360		440	<5	3100
PE161850	MDPZ7451B	6/07/2022	Hydrasleeve	60	7.7	16000	11000	270	360	2700	270	<0.025	<0.025	0.41	4100	2500		53		6.8	410		490	<5	2200
PE161850	MDPZ7451C	6/07/2022	Hydrasleeve	20	7.6	3000	1800	75	71	350	52	<0.005	<0.005	<0.001	670	400		66		27	210		250	<5	480
PE161850	MDPZ7452A	6/07/2022	Hydrasleeve	70	7.9	13000	8100	200	330	2200	220	0.027	<0.025	0.35	3600	1500		44		0.3	630		770	<5	1800
PE161850	MDPZ7452B	6/07/2022	Hydrasleeve	45	7.7	7600	4600	110	150	1200	120	<0.01	<0.01	<0.002	1900	950		75		25	420		510	<5	900
PE161850	MDPZ7452C	6/07/2022	Hydrasleeve	20	7.8	6800	3900	98	130	1100	110	<0.01	<0.01	<0.002	1600	880		78		26	440		530	<5	800
PE161850	MDPZ7453A	6/07/2022	Hydrasleeve	65	7.6	21000	15000	320	490	3700	410	<0.025	<0.025	<0.005	6000	3400		65		6	420		510	<5	2800
PE161850	MDPZ7453B	6/07/2022	Hydrasleeve	40	7.7	16000	10000	320	520	2600	290	<0.025	<0.025	<0.005	3900	2700		96		23	390		480	<5	3000
PE161850	MDPZ7453C	6/07/2022	Hydrasleeve	10	7.7	16000	10000	340	570	2500	280	<0.025	<0.025	<0.005	4100	2600		97		29	380		470	<5	3200
PE161850	MDPZ7454	9/07/2022	Hydrasleeve	50	7.1	670	440	24	21	62	25	<0.005	<0.005	0.008	87	140		47		8.6	88		110	<5	150
PE161850	MDPZ7455	10/07/2022	Hydrasleeve	50	3.5	1200	850	63	35	50	40	6.1	28	0.44	82	440		80		<0.2	<5		<5	<5	300
PE161850	MDPZ7456A	9/07/2022	Hydrasleeve	105	8.1	3600	2100	90	96	450	53	<0.005	<0.005	0.005	840	410		49		12	230		280	<5	620
PE161850	MDPZ7456B	9/07/2022	Hydrasleeve	55	7.6	3900	2300	110	92	500	52	<0.005	<0.005	<0.001	930	430		64		24	170		200	<5	660
PE161850	MDPZ7456C	9/07/2022	Hydrasleeve	20	7.7	3400	2100	100	86	390	54	<0.005	<0.005	<0.001	760	420		80		27	170		200	<5	610
PE161850	MDPZ7457A	7/07/2022	Hydrasleeve	90	7.5	16000	10000	220	340	2700	280	<0.025	0.14	1.1	4100	2200		18		1.4	410		500	<5	1900
PE161850	MDPZ7457B	7/07/2022	Hydrasleeve	45	7.7	11000	7300	200	210	1900	180	<0.025	<0.025	0.12	2900	1700		62		1.5	330		400	<5	1400
PE161850	MDPZ7457C	7/07/2022	Hydrasleeve	28	7.8	7600	4400	130	140	1200	120	<0.01	<0.01	0.008	1800	970		81		19	400		490	<5	890
PE161850	MDPZ7458A	7/07/2022	Hydrasleeve	68	7.7	14000	8400	210	310	2300	220	<0.025	<0.025	0.057	3600	1700		48		19	420		510	<5	1800
PE161850	MDPZ7458B	7/07/2022	Hydrasleeve	50	7.8	15000	9300	200	290	2500	240	<0.025	<0.025	0.01	3900	1800		56		17	440		530	<5	1700
PE161850	MDPZ7459	6/07/2022	Hydrasleeve	20	7.9	600	390	40	21	42	1.6	<0.005	<0.005	<0.001	46	11		82		7.6	240		290	<5	190
PE161850	MDPZ7460A	9/07/2022	Hydrasleeve	85	7.8	6300	3800	120	130	980	90	<0.005	0.11	0.36	1500	690		28		<0.2	310		380	<5	840
PE161850	MDPZ7460B	9/07/2022	Hydrasleeve	49	7.8	4600	2800	120	100	610	64	<0.005	<0.005	<0.001	1200	500		63		22	200		250	<5	730
PE161850	MDPZ7460C	9/07/2022	Hydrasleeve	25	7.7	4500	2700	120	110	580	63	<0.005	<0.005	<0.001	1100	480		68		22	200		250	<5	730
PE161850	MDPZ7461	7/07/2022	Hydrasleeve	20	7.8	6400	3900	110	150	1000	96	<0.005	<0.005	<0.001	1600	750		74		28	370		450	<5	900
PE161850	MDPZ7463 Lower	6/07/2022	Hydrasleeve	80	7.6	8600	5500	150	210	1300	120	<0.005	<0.005	<0.001	2100	1300		54		14	350		420	<5	1200
PE161850	MDPZ7463 Upper	6/07/2022	Hydrasleeve	15	7.6	4000	2500	81	81	570	51	<0.005	<0.005	<0.001	810	570		66		16	380		460	<5	530
PE161850	MDPZ7464 Lower	6/07/2022	Hydrasleeve	85	7.6	16000	11000	240	420	2900	310	<0.025	<0.025	<0.005	4200	2500		23		2.1	350		420	<5	2300
PE161850	MDPZ7464 Upper	6/07/2022	Hydrasleeve	15	7.8	1800	1100	53	45	210	21	<0.005	<0.005	<0.001	320	260		65		7.3	350		430	<5	320
PE161850	MDPZ7465	9/07/2022	Hydrasleeve	90	6.9	1800	1000	39	45	180	16	<0.005	37	0.31	450	6		42		<0.2	180		220	<5	280
PE161850	MDPZ7466 Lower	9/07/2022	Hydrasleeve	60	4	1500	1100	87	61	90	53	4.7	0.037	2.4	150	560		80		5.4	<5		<5	<5	470
PE161850	MDPZ7466 Upper	9/07/2022	Hydrasleeve	40	6.7	290	240	7.8	9.7	27	8	0.006	<0.005	0.002	47	20		61		23	40		49	<5	59
PE161850	MDPZ7468A	6/07/2022	Hydrasleeve	62	7.5	21000	15000	270	500	3900	420	<0.025	0.49	1.1	6100	3400		15		0.3	380		470	<5	2700
PE161850	MDPZ7468B	6/07/2022	Hydrasleeve	50	7.6	15000	10000	210	380	2600	270	<0.025	<0.025	<0.005	3900	2300		53		12	360		440	<5	2100
PE161850	MDPZ7468C	6/07/2022	Hydrasleeve	85	7.5	10000	6600	160	240	1600	170	<0.025	<0.025	<0.005	2500	1600		54		18	320		390	<5	1400
PE161850	MDPZ7469A	8/07/2022	Hydrasleeve	60	7.2	16000	10000	200	350	2800	260	<0.025	2.4	4.1	4200	2300		15		0.2	300		370	<5	1900
PE161850	MDPZ7469B	8/07/2022	Hydrasleeve	30	7.7	3200	1700	94	78	390	49	<0.005	<0.005	0.005	750	410		65		27	190		230	<5	560
PE161850	MDPZ7469C	8/07/2022	Hydrasleeve	100	7.8	2900	1700	91	75	320	46	<0.005	<0.005	<0.001	600	360		66		29	210		250	<5	540
PE161850	MDPZ7470A	8/07/2022	Hydrasleeve	75	7.7	8500	5300	150	170	1300	130	<0.01	0.015	1.5	2200	850		57		4.6	380		470	<5	1000
PE161850	MDPZ7470B	8/07/2022	Hydrasleeve	35	7.8	6200	3800	100	110	1000	110	<0.005	<0.005	0.002	1600	690		85		17	350		420	<5	690
PE161850	MDPZ7470C	8/07/2022	Hydrasleeve	90	7.9	6200	3800	100	100	1000	120	<0.005	<0.005	0.006	1500	710		86		17	360		440	<5	680
PE161850	MDPZ7471A	6/07/2022	Hydrasleeve	45	7.8	8800	5500	130	210	1400	130	<0.01	<0.01	0.005	2200	1200		66		20	410		490	<5	1200
PE161850	MDPZ7471C	6/07/2022	Hydrasleeve	20	7.8	8400	5100	110	190	1300	110	<0.01	<0.01	<0.002	2000	980		87		21	420		520	<5	1000
PE161850	MDPZ7467 Lower	10/07/2022	Hydrasleeve	62	7.4	1900	1300	150	66	140	30	<0.005	1.9	0.97	160	450		28		<0.2	390		470	<5	660
PE161850	MDPZ7467 Upper	10/07/2022	Hydrasleeve	50	7.2	1400	930	90	45	110	27	<0.005	6.9	1.2	130	350		32		<0.2	220		260	<5	410
PE161850	MDPZ9205	9/07/2022	Hydrasleeve	35	7.5	2000	1300	80	57	220	32	<0.005	<0.005	<0.001	380	290		58		24	140		180	<5	430

Lab Report	Bore ID	Sample Date	Sample Type	Sample Depth	pH	Conductivity	Total Dissolved Solids	Calcium - Dissolved	Magnesium - Dissolved	Sodium - Dissolved	Potassium - Dissolved	Aluminium - Dissolved	Iron - Dissolved	Manganese - Dissolved	Chloride	Sulfate	Filterable Reactive Phosphorus	Reactive Silica	Ammonia-N	Nitrate-N	Total Alkalinity	Bicarbonate	Bicarbonate	Carbonate	Hardness
					pH units	uS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg CaCO3/L	mg CaCO3/L	mg HCO3/L	mg CO3/L	mg CaCO3/L
PE161850	MDPZ9211	7/07/2022	Hydrasleeve	48	7.8	11000	6400	150	230	1700	160	<0.01	<0.01	<0.002	2700	1300		60		29	430		520	<5	1300
PE161850	MDPZ9212D	7/07/2022	Hydrasleeve	105	7.7	17000	11000	240	400	3000	280	0.035	<0.025	0.12	4700	2300		42		8.6	420		520	<5	2200
PE161850	MDPZ9212S	7/07/2022	Hydrasleeve	20	8	16000	9900	150	340	2800	270	<0.025	<0.025	<0.005	4200	1900		85		18	470		570	<5	1800
PE161850	MDPZ9213	6/07/2022	Hydrasleeve	40	7.8	2000	1200	82	88	160	21	<0.005	<0.005	<0.001	330	250		66		30	380		460	<5	570
PE161850	MDPZ9214	6/07/2022	Hydrasleeve	40	7.9	4800	2800	68	110	730	67	<0.005	<0.005	<0.001	1000	590		81		27	400		490	<5	600
PE161850	MDPZ9215D	6/07/2022	Hydrasleeve	80	7.9	7700	4800	110	180	1200	120	<0.01	<0.01	<0.002	1900	970		56		19	400		490	<5	1000
PE161850	MDPZ9215S	6/07/2022	Hydrasleeve	20	7.9	5500	3300	91	130	860	83	<0.005	<0.005	<0.001	1300	750		59		23	370		450	<5	750
PE161850	MDPZ9216	6/07/2022	Hydrasleeve	90	7.6	19000	14000	300	570	3100	340	<0.025	<0.025	1.3	5500	3000		28		0.8	400		480	<5	3100
PE161850	MDPZ9217	5/07/2022	Hydrasleeve	30	7.6	7800	5000	160	220	1200	110	<0.005	<0.005	<0.001	2000	1100		50		18	320		390	<5	1300
PE161850	MDPZ9218	5/07/2022	Hydrasleeve	30	7.7	5100	3100	100	130	580	60	<0.005	0.006	0.004	1200	710		43		7	310		380	<5	770
PE161850	MDPZ9219	5/07/2022	Hydrasleeve	30	7.7	10000	6400	120	200	670	78	<0.005	<0.005	0.001	2800	1400		69		13	420		510	<5	1100
PE161850	MDPZ9220	5/07/2022	Hydrasleeve	30	7.8	2500	1500	79	82	260	32	<0.005	<0.005	0.069	460	290		26		1.6	290		360	<5	540
PE161850	MDPZ9221	5/07/2022	Hydrasleeve	30	7.8	3900	2400	110	120	450	47	<0.005	<0.005	<0.001	860	470		68		18	330		410	<5	790
PE164581	MD5382	23/10/2022	Hydrasleeve	45	7.7	1700	1100	220	98	110	20	<0.005	<0.005	2	160	320		49		9.4	330		400	<5	950
PE164581	MD5461	23/10/2022	Hydrasleeve	50	7.8	2800	1700	81	79	380	42	<0.005	<0.005	<0.001	550	330		64		36	220		270	<5	530
PE164581	MDPZ7449A	26/10/2022	Hydrasleeve	65	7.6	1900	1200	120	69	160	33	<0.005	<0.005	0.22	250	360		18		0.3	360		440	<5	600
PE164581	MDPZ7449B	26/10/2022	Hydrasleeve	25	7.4	1800	1100	76	58	180	32	<0.005	<0.005	<0.001	310	280		71		26	160		190	<5	430
PE164581	MDPZ7449C	26/10/2022	Hydrasleeve	9	7.6	4700	3200	240	180	480	61	<0.005	<0.005	<0.001	1100	900		100		50	160		200	<5	1300
PE164581	MDPZ7450A	22/10/2022	Hydrasleeve	98	7.7	7700	4800	170	270	2200	220	<0.025	<0.025	0.22	1800	980		39		10	310		380	<5	1500
PE164581	MDPZ7450B	22/10/2022	Hydrasleeve	35	7.8	1300	810	68	52	130	13	<0.005	<0.005	<0.001	150	150		64		18	310		370	<5	380
PE164581	MDPZ7450C	22/10/2022	Hydrasleeve	20	7.9	930	550	32	23	120	11	<0.005	<0.005	<0.001	130	44		72		5.4	230		270	<5	170
PE164581	MDPZ7451A	22/10/2022	Hydrasleeve	105	7.5	23000	15000	310	580	4200	440	<0.025	<0.025	2.7	6300	3200		29		<0.2	330		400	<5	3200
PE164581	MDPZ7451B	22/10/2022	Hydrasleeve	60	7.8	16000	10000	270	380	2600	270	<0.025	<0.025	0.05	4000	2300		52		4.1	370		460	<5	2200
PE164581	MDPZ7451C	22/10/2022	Hydrasleeve	20	7.7	3000	1800	81	77	390	54	<0.005	<0.005	<0.001	610	360		64		26	190		240	<5	520
PE164581	MDPZ7452A	22/10/2022	Hydrasleeve	70	8	13000	8000	190	310	2200	220	<0.025	<0.025	0.45	3400	1300		47		0.3	570		690	<5	1700
PE164581	MDPZ7452B	22/10/2022	Hydrasleeve	45	7.9	6700	3800	110	150	1200	120	<0.01	<0.01	<0.002	1600	820		77		23	410		500	<5	900
PE164581	MDPZ7452C	22/10/2022	Hydrasleeve	20	7.8	7700	4500	100	140	1100	100	<0.005	<0.005	<0.001	4000	2600		73		24	390		480	<5	830
PE164581	MDPZ7453A	22/10/2022	Hydrasleeve	65	7.6	22000	14000	340	530	3800	390	<0.025	<0.025	<0.005	6000	3200		65		4.1	400		480	<5	3000
PE164581	MDPZ7453B	22/10/2022	Hydrasleeve	40	7.7	16000	11000	300	460	2400	280	<0.025	<0.025	<0.005	3900	2600		97		23	360		440	<5	2600
PE164581	MDPZ7453C	22/10/2022	Hydrasleeve	10	7.7	16000	11000	310	490	2400	280	<0.025	<0.025	<0.005	4100	2400		99		33	370		450	<5	2800
PE164581	MDPZ7454	26/10/2022	Hydrasleeve	50	6.9	740	470	28	25	68	28	<0.005	<0.005	<0.001	92	180		42		7.5	69		84	<5	170
PE164581	MDPZ7455	26/10/2022	Hydrasleeve	50	3.5	1200	870	62	35	48	39				83	490		80			<5		<5	<5	300
PE164581	MDPZ7456A	26/10/2022	Hydrasleeve	105	8	3600	2200	94	97	470	52				850	440		50			210		260	<5	630
PE164581	MDPZ7456B	26/10/2022	Hydrasleeve	55	7.6	3800	2400	110	93	500	49				960	490		64			160		190	<5	660
PE164581	MDPZ7456C	26/10/2022	Hydrasleeve	20	7.5	3200	2000	99	85	400	49				750	440		80			160		190	<5	600
PE164581	MDPZ7457A	26/10/2022	Hydrasleeve	90	7.5	15000	10000	200	330	2600	280	<0.025	<0.025	0.66	4100	2300		19		1.7	380		470	<5	1900
PE164581	MDPZ7457B	26/10/2022	Hydrasleeve	45	7.7	12000	7300	200	200	1900	180	<0.025	2.4	0.032	3000	1900		67		3.8	240		300	<5	1300
PE164581	MDPZ7457C	26/10/2022	Hydrasleeve	28	7.9	6800	4200	130	140	1100	120	<0.005	<0.005	0.008	1700	1000		82		12	340		410	<5	890
PE164581	MDPZ7458A	23/10/2022	Hydrasleeve	68	7.8	14000	8600	190	270	2200	220	<0.025	<0.025	0.028	3500	1600		49		18	390		470	<5	1600
PE164581	MDPZ7458B	23/10/2022	Hydrasleeve	50	7.8	15000	9300	190	290	2400	230	<0.025	<0.025	<0.005	3700	1700		57		13	410		500	<5	1600
PE164581	MDPZ7458C	23/10/2022	Hydrasleeve	8	8.1	14000	8300	110	230	2200	220	<0.025	<0.025	<0.005	3400	1400		97		19	520		640	<5	1200
PE164581	MDPZ7459	21/10/2022	Hydrasleeve	20	7.9	560	370	43	23	46	1.7	<0.005	<0.005	<0.001	38	10		86		4.6	230		290	<5	200
PE164581	MDPZ7460A	26/10/2022	Hydrasleeve	85	7.8	6200	3800	120	120	900	84				1600	720		28			290		350	<5	800
PE164581	MDPZ7460B	26/10/2022	Hydrasleeve	49	7.7	4600	2800	120	110	630	62				1200	550		64			190		240	<5	760
PE164581	MDPZ7460C	26/10/2022	Hydrasleeve	25	7.7	4400	2700	130	110	610	63				1100	540		69			190		240	<5	770
PE164581	MDPZ7461	23/10/2022	Hydrasleeve	20	7.9	6500	3900	110	140	940	86	<0.005	<0.005	<0.001	1600	680		76		27	350		430	<5	870
PE164581	MDPZ7463 Lower	21/10/2022	Hydrasleeve	80	7.7	6900	4300	160	220	1400	130	N.A.	N.A.	N.A.	1700	1100		60		N.A.	330		410	<5	1300
PE164581	MDPZ7463 Upper	21/10/2022	Hydrasleeve	15	7.8	4000	2500	89	89	620	52	<0.005	<0.005	<0.001	770	540		66		15	350		430	<5	590
PE164581	MDPZ7464 Lower	21/10/2022	Hydrasleeve	80	7.7	8600	5200	220	390	2600	290	<0.025	<0.025	<0.005	2100	1200		43		4.7	330		400	<5	2200
PE164581	MDPZ7464 Upper	21/10/2022	Hydrasleeve	15	8	1300	800	42	36	170	20	<0.005	<0.005	<0.001	140	130		63		5.4	310		380	<5	250
PE164581	MDPZ7465	26/10/2022	Hydrasleeve	90	6.9	1700	1000	41	46	190	17				440	<1		50			99		120	<5	290
PE164581	MDPZ7466 Lower	26/10/2022	Hydrasleeve	60	4	1500	1100	7.8	10	27	8.2	N.A.	N.A.	N.A.	150	610		82		N.A.	<5		<5	<5	61
PE164581	MDPZ7466 Upper	26/10/2022	Hydrasleeve	40	6.6	290	230	90	66	98	52	N.A.	N.A.	N.A.	45	13		61		N.A.	36		44	<5	500
PE164581	MDPZ7467 Lower	26/10/2022	Hydrasleeve	62	7.3	1800	1200	150	66	150	29	N.A.	N.A.	N.A.	150	470		28		N.A.	320		390	<5	650
PE164581	MDPZ7467 Upper	26/10/2022	Hydrasleeve	50	7.2	1400	930	90	47	110	27	N.A.	N.A.	N.A.	130	350		33		N.A.	190		230	<5	420
PE164581	MDPZ7468A	21/10/2022	Hydrasleeve	85	7.5	22000	16000	280	520	3800	390	<0.025	<0.025	0.95	6200	3200		15		<0.2	360		430	<5	2800
PE164581	MDPZ7468B	21/10/2022	Hydrasleeve	60	7.6	15000	9600	200	340	2500	270	<0.005	<0.005	0.002	3900	2200		51		12	330		410	<5	1900
PE164581	MDPZ7468C	21/10/2022	Hydrasleeve	30	7.7	10000	6600	160	230	1700	180	<0.01	<0.01	<0.002	2600	1500		53		18	300		370	<5	1300
PE164581	MDPZ7469A	26/10/2022	Hydrasleeve	100	7.2	15000	10000	190	310	2600	250	<0.025	0.028	2.5	4100	2300		22		<0.2	320		390	<5	1700
PE164581	MDPZ7469B	26/10/2022	Hydrasleeve	75	7.6	3200	1900	94	81	400	48	<0.005	<0.005	<0.001	700	420		65		26	180		220	<5	570
PE164581	MDPZ7469C	26/10/2022	Hydrasleeve	35	7.7	2800	1700	91	76	340	45	<0.005	<0.005	<0.001	600	360		68		3.1	190		230	<5	540
PE164581	MDPZ7470A	26/10/2022	Hydrasleeve	90	7.6	8400	5200	140	160	1300	130				2300	1000		56			300		370	<5	1000
PE164581	MDPZ7470B	26/10/2022	Hydrasleeve	45	7.8	6100	3700	110	110	980	100				1600	740		84			320		390	<5	730
PE164581	MDPZ7470C	26/10/2022	Hydrasleeve	20	7.8	6100	3800	100	110	950	120				1500	720		85			350		420	<5	690
PE164581	MDPZ7471A	19/10/2022	Hydrasleeve	72	7.9	9000	5300	130	220	1300	120	<0.01	<0.01	0.004	2200	1100		68		20	380		470	<5	1200
PE164581	MDPZ7471C	19/10/2022	Hydrasleeve	15	7.9	8000	4900	110	190	1300	98	<0.01	<0.01	<0.002	1900	910		86		21	400		490	<5	1100
PE164581	MDPZ9205	26/10/2022	Hydrasleeve	35	7.3	2100	1300	81	60	250	33				410	320		56			130		160	<5	450
PE164581	MDPZ9211	23/10/2022	Hydrasleeve	48	7.8	12000	7100	160	230	1800	180	<0.025	<0.025	0.15	2900	1300		53		22	390		480	<5	1400
PE164581	MDPZ9212D	23/10/2022	Hydrasleeve	105	7.7	18000	11000	220	390	2900	290	<0.025	<0.025	0.21	4600	2200		40		7.3	390		480	<5	2200
PE164581	MDPZ9212S	23/10/2022	Hydrasleeve	20	8	16000	10000	130	320	2600	270	<0.025	<0.025	<0.005	4200	1800		87		19	440		540	<5	1600
PE164581	MDPZ9213	19/10/2022	Hydrasleeve	40	7.9	2100	1300	92	98	180	23	<0.005	<0.005	<0.001	310	240		67		28	350		430	<5	630
PE164581	MDPZ9214	19/10/2022	Hydrasleeve	40	7.9	4900	3000	73	110	740	66	<0.005	<0.005	<0.001	1000	570		82		25	380		470	<5	640
PE164581	MDPZ9215D	19/10/2022	Hydrasleeve	80	7.8	7300	4300	100	160	1100	100	<0.005	<0.005	<0.001	1700	850		60		20	370		450	<5	910
PE164581	MDPZ9215S	19/10/2022	Hydrasleeve	20	7.9	5600	4300	92	130	840	80	<0.005	<0.005	<0.001	1300	690		56		21	350		430	<5	760
PE164581	MDPZ9216	19/10/2022	Hydrasleeve	90	7.5	20000	14000	330	610	3200	340	<0.025	<0.025	0.97	5600	3000		28		0.3	330		410	<5	3300
PE164581	MDPZ9217	23/10/2022	Hydrasleeve	30	7.8	5900	3600	170	230	1100	99	<0.005	<0.005	0.001	1400	720		41		13	240		290	<5	1400
PE164581	MDPZ9218	23/10/2022	Hydrasleeve	30	7.9	4200	2600	110	130	570	56	<0.005	0.073	0.015	890	480		51		14	290		360	<5	780
PE164581	MDPZ9219	24/10/2022	Hydrasleeve	30	7.9	4100	2500	110	130	490	50	<0.005	<0.005	0.002	910	450		60		13	280		350	<5	790
PE164581	MDPZ9220	24/10/2022	Hydrasleeve	30	8	2700	1600	83	86	270	33	<0.005	0.013	0.033	530	290		23		<0.2	270		330	<5	560
PE164581	MDPZ9221	24/10/2022	Hydrasleeve	30	8	3800	2300	110	130	470	48	<0.005	<0.005	<0.001	790	420		69		14	310		380	<5	820
PE168102 R0	MDPZ9221	2/05/2023	Hydrasleeve	30	8	3700	2300	110	120	430	48	<0.005	<0.005	<0.001	800	410		65		3.8	300	300	370	<5	780
PE168102 R0	MDPZ9220	2/05/2023	Hydrasleeve	30	8	2500	1500	80	85	260	33	<0.005	0.036	0.023	480	250		26		0.45	270	270	330	<5	550
PE168102 R0	MDPZ9219	2/05/2023	Hydrasleeve	30	7.8	3800	2300	100	120	450	48	0.005	0.008	<0.001	840	390	0.005	51	0.02	3.2	280	280	340	<5	750
PE168102 R0	MDPZ9218	2/05/2023	Hydrasleeve	30	7.8	4800	2900	110	140	610	61	<0.005	0.078	0.47	1100	560		43		2.1	320	320	390	<5	850
PE168102 R0	MD5461	3/05/2023	Hydrasleeve	50	7.7	2900	1700	75	74	330	41	<0.005	<0.005	0.006	570	310	0.034	61	0.06	7.7	290	230	270	<5	490
PE168102 R0	MDPZ9217	3/05/2023	Hydrasleeve	30	7.7	7600	4800	160	230	1100	100	<0.005	<0.005	<0.001	1800	970		44		4	290	290	360	<5	1300
PE168102 R0	MD5382	3/05/2023	Hydrasleeve	45	7.5	1700	1100	140	73	100	19	<0.005	0.46	0.62	170	300		44		2.2	320	320	390	<5	650
PE168102 R0	MDPZ7463S	3/05/2023	Hydrasleeve	15	7.8	4000	2400	82	86	570	53	<0.005	<0.005	<0.001	780	520		65		3.8	350	350	430	<5	560
PE168102 R0	MDPZ7463D	3/05/2023	Hydrasleeve	80	7.7	8200	5100	140	200	1300	120	<0.005	<0.005	<0.001	2000	1100		49		3.2	330	330	400	<5	1200
PE168102 R0	MDPZ7468A	3/05/2023	Hydrasleeve	85	7.5	21000	14000	270	500	3800	410	<0.050	1.1	0.95	5700	3000		19		0.31	360	360	440	<5	2700
PE168102 R0	MDPZ7468B	3/05/2023	Hydrasleeve	60	7.6	15000	9900	200	360	2600	270	<0.025	0.034	<0.005	3900	2100		47		2.7	340	340	410	<5	2000
PE168102 R0	MDPZ7468C	3/05/2023	Hydrasleeve	30	7.6	11000	6500	160	240	1700	180	<0.025	<0.025	<0.005	2600	1400		47		4.2	300	300	370	<5	1400
PE168102 R0	MDPZ7471A	3/05/2023	Hydrasleeve	72	7.8	8900	5400	120	210	1400	130	<0.010	<0.010	0.004	2200	1100		66		4.7	380	380	470	<5	1200
PE168102 R0	MDPZ7471C	3/05/2023	Hydrasleeve	15	8	8000	4900	79	140	1100	86	<0.005	<0.005	<0.001	1900	890		87		4.9	400	400	490	<5	780
PE168102 R0	MDPZ9216	3/05/2023	Hydrasleeve	90	7.6	20000	13000	310	580	3200	320	<0.025	0.21	0.001	5400	2900		25		0.1	330	330	400	<5	3200
PE168102 R0	MDPZ9215S	3/05/2023	Hydrasleeve	20	8	5600	3400	87	130	860	81	<0.005	<0.005	<0.001	1300	680	0.01	57	<0.01	5.8	360	360	440	<5	750
PE168102 R0	MDPZ9215D	3/05/2023	Hydrasleeve	80	8	7000	4300	97	160	1100	100	<0.005	<0.005	<0.001	1700	840		59		4.9	350	350	430	<5	900
PE168102 R0	MDPZ9214	3/05/2023	Hydrasleeve	40	8	4900	3000	72	110	720	64	<0.005	<0.005	<0.001	1100	570		81		6.8	380	380	460	<5	650

Lab Report	Bore ID	Sample Date	Sample Type	Sample Depth	pH	Conductivity	Total Dissolved Solids	Calcium - Dissolved	Magnesium - Dissolved	Sodium - Dissolved	Potassium - Dissolved	Aluminium - Dissolved	Iron - Dissolved	Manganese - Dissolved	Chloride	Sulfate	Filterable Reactive Phosphorus	Reactive Silica	Ammonia-N	Nitrate-N	Total Alkalinity	Bicarbonate	Bicarbonate	Carbonate	Hardness
					pH units	uS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg CaCO3/L	mg CaCO3/L	mg HCO3/L	mg CO3/L	mg CaCO3/L
PE168102 R0	MDPZ9213	3/05/2023	Hydrasleeve	40	7.9	2000	1200	85	95	170	23	0.006	<0.005	<0.001	320	230		67		6.8	350	350	430	<5	600
PE168102 R0	MDPZ7450C	4/05/2023	Hydrasleeve	20	8	1300	730	54	42	120	13	<0.005	<0.005	<0.001	250	37		73		2.3	220	220	260	<5	310
PE168102 R0	MDPZ7454	4/05/2023	Hydrasleeve	50	7	690	460	21	20	70	24	<0.005	0.006	0.05	64	140		39		1.9	87	87	110	<5	130
PE168102 R0	MDPZ7460C	4/05/2023	Hydrasleeve	25	7.7	4400	2700	120	110	570	59	<0.005	<0.005	<0.001	1100	470		66		5.2	190	190	240	<5	740
PE168102 R0	MDPZ7464S	3/05/2023	Hydrasleeve	15	8	1200	760	35	32	150	19	<0.005	<0.005	<0.001	140	140		68		1.7	300	300	360	<5	220
PE168102 R0	MDPZ7464D	3/05/2023	Hydrasleeve	80	7.6	15000	9800	220	400	2900	300	<0.025	0.025	<0.005	4000	2200		24		0.44	330	330	400	<5	2200
PE168204 R0	MDPZ7453A	4/05/2023	Hydrasleeve	65	7.5	22000	14000	330	510	3800	400	<0.025	<0.025	<0.005	6000	3100		61		1.2	390	390	470	<5	2900
PE168204 R0	MDPZ7453B	4/05/2023	Hydrasleeve	40	7.6	16000	11000	290	470	2600	280	<0.025	<0.025	<0.005	4000	2600		97		5.1	360	360	440	<5	2700
PE168204 R0	MDPZ7453C	4/05/2023	Hydrasleeve	10	7.6	16000	11000	300	510	2600	280	<0.025	<0.025	<0.005	4300	2500		100		7.3	370	370	450	<5	2900
PE168204 R0	MDPZ7452A	4/05/2023	Hydrasleeve	70	7.8	13000	8500	190	330	2300	220	<0.025	1.1	0.43	3400	1300		44		0.16	610	610	750	<5	1800
PE168204 R0	MDPZ7452B	4/05/2023	Hydrasleeve	45	7.7	7600	4700	110	150	1200	120	<0.010	<0.010	<0.002	1900	960		72		5	400	400	480	<5	910
PE168204 R0	MDPZ7452C	4/05/2023	Hydrasleeve	20	7.8	6800	4100	95	130	1100	110	<0.010	<0.010	<0.002	1600	800		75		5.1	410	410	500	<5	790
PE168204 R0	MDPZ7451A	4/05/2023	Hydrasleeve	105	7.4	23000	16000	300	570	4200	450	<0.025	0.23	2.3	6500	3200		27		<0.05	350	350	430	<5	3100
PE168204 R0	MDPZ7451B	4/05/2023	Hydrasleeve	60	7.6	16000	11000	240	360	2800	270	<0.025	<0.025	0.26	4100	2200		53		1.4	380	380	460	<5	2100
PE168204 R0	MDPZ7451C	4/05/2023	Hydrasleeve	20	7.5	3000	2200	86	82	390	54	<0.005	<0.005	<0.001	660	350		64		5.5	200	200	240	<5	550
PE168204 R0	MDPZ7450A	4/05/2023	Hydrasleeve	98	7.5	13000	8100	130	180	1300	140	<0.010	0.032	0.065	3200	1800		24		0.7	330	330	410	<5	1100
PE168204 R0	MDPZ7450B	4/05/2023	Hydrasleeve	35	7.7	1300	770	62	47	130	12	<0.005	<0.005	0.005	160	150		64		3.7	310	310	380	<5	350
PE168204 R0	MDPZ7449A	4/05/2023	Hydrasleeve	65	7.6	1900	1300	130	72	160	32	<0.005	0.47	0.2	240	320		16		<0.05	370	370	450	<5	620
PE168204 R0	MDPZ7449B	4/05/2023	Hydrasleeve	25	7.4	1900	1200	80	63	180	33	<0.005	<0.005	<0.001	310	270		70		5.6	150	150	190	<5	460
PE168204 R0	MDPZ7449C	4/05/2023	Hydrasleeve	9	7.6	4600	3100	210	160	450	56	<0.005	<0.005	<0.001	1000	770	0.042	98	<0.01	11	160	160	200	<5	1200
PE168204 R0	MDPZ9212D	4/05/2023	Hydrasleeve	105	7.6	17000	12000	220	410	3200	280	<0.025	<0.025	0.14	4700	2200		40		1.3	390	390	480	<5	2200
PE168204 R0	MDPZ9212S	4/05/2023	Hydrasleeve	20	8	16000	10000	130	340	2800	270	<0.025	<0.025	<0.005	4100	1700		88		4.1	440	440	530	<5	1700
PE168204 R0	MDPZ9211	4/05/2023	Hydrasleeve	48	7.7	11000	6500	150	220	1700	170	<0.025	<0.025	<0.005	2800	1200		53		4.8	390	390	470	<5	1300
PE168204 R0	MDPZ7461	4/05/2023	Hydrasleeve	20	7.9	6400	3900	110	150	970	91	<0.005	<0.005	<0.001	1600	650		74		5.6	350	350	430	<5	880
PE168204 R0	MDPZ7458A	4/05/2023	Hydrasleeve	68	7.7	14000	8400	190	290	2300	240	<0.025	<0.025	0.065	3500	1500		47		3.7	400	400	480	<5	1700
PE168204 R0	MDPZ7458B	4/05/2023	Hydrasleeve	50	7.8	14000	9000	180	290	2600	250	<0.025	<0.025	<0.005	3800	1600		54		3.3	410	410	500	<5	1600
PE168204 R0	MDPZ7458C	4/05/2023	Hydrasleeve	8	8	13000	8200	100	230	2200	230	<0.025	<0.025	<0.005	3400	1300		95		4.7	520	520	640	<5	1200
PE168204 R0	MDPZ7457A	4/05/2023	Hydrasleeve	90	7.5	16000	9900	200	330	2800	280	<0.025	0.03	0.6	4000	2000		18		0.45	390	390	470	<5	1800
PE168204 R0	MDPZ7457B	5/05/2023	Hydrasleeve	45	7.8	12000	7600	190	210	1900	190	<0.010	0.012	0.051	3000	1600		65		0.81	250	250	310	<5	1300
PE168204 R0	MDPZ7457C	5/05/2023	Hydrasleeve	28	7.9	7300	4600	120	140	1100	120	<0.010	<0.010	0.004	1800	900	0.031	80	250	3.2	360	360	440	<5	870
PE168204 R0	MDPZ7469A	5/05/2023	Hydrasleeve	100	7.1	16000	11000	170	310	2700	270	<0.025	1.4	2.2	4200	2000		17		<0.05	290	290	360	<5	1700
PE168204 R0	MDPZ7469B	5/05/2023	Hydrasleeve	75	7.7	3200	1900	90	78	390	48	0.009	<0.005	<0.001	710	360		64		5.4	180	180	210	<5	550
PE168204 R0	MDPZ7469C	5/05/2023	Hydrasleeve	35	7.8	2800	1800	84	71	320	45	<0.005	0.006	<0.001	600	320		67		5.5	190	190	230	<5	500
PE168204 R0	MDPZ7470A	5/05/2023	Hydrasleeve	90	7.8	8600	5300	140	170	1300	140	0.01	0.019	0.83	2200	890		53		2.1	320	320	390	<5	1000
PE168204 R0	MDPZ7470B	5/05/2023	Hydrasleeve	45	7.8	6200	3800	100	110	970	110	<0.005	<0.005	<0.001	1500	620		83		3.7	320	320	390	<5	680
PE168204 R0	MDPZ7470C	5/05/2023	Hydrasleeve	20	7.9	6200	3700	97	99	940	120	<0.005	<0.005	0.009	1500	620	0.12	82	<0.01	3.8	350	350	420	<5	650
PE168204 R0	MDPZ7460A	5/05/2023	Hydrasleeve	85	7.8	6200	3700	110	120	870	91	<0.005	0.27	0.2	1600	620		28		0.08	280	280	340	<5	740
PE168204 R0	MDPZ7460B	5/05/2023	Hydrasleeve	49	7.7	4600	2900	120	110	630	61	<0.005	<0.005	<0.001	1200	480		63		4.5	200	200	250	<5	740
PE168204 R0	MDPZ7456A	5/05/2023	Hydrasleeve	105	8	3600	2200	93	94	460	55	<0.005	<0.005	0.001	850	370		50		3	210	210	260	<5	620
PE168204 R0	MDPZ7456B	5/05/2023	Hydrasleeve	55	7.6	3900	2400	110	93	510	52	<0.005	<0.005	<0.001	950	400		64		4.8	160	160	190	<5	660
PE168204 R0	MDPZ7456C	5/05/2023	Hydrasleeve	20	7.7	3600	2200	100	93	440	56	<0.005	<0.005	<0.001	820	430		86		6.2	150	150	190	<5	640
PE168204 R0	MDPZ9205	5/05/2023	Hydrasleeve	35	7.5	2100	1300	63	46	170	26	<0.005	<0.005	<0.001	380	280		57		4.5	140	140	160	<5	350
PE168204 R0	MDPZ7465	5/05/2023	Hydrasleeve	90	7	1600	920	38	42	160	15	<0.005	33	0.28	430	3	<0.002	41	<0.01	<0.05	120	120	150	<5	270
PE168204 R0	MDPZ7466S	5/05/2023	Hydrasleeve	40	6.7	290	230	7.1	9.1	25	7.5	0.007	0.025	0.001	45	13		61		4.6	36	36	44	<5	55
PE168204 R0	MDPZ7466D	5/05/2023	Hydrasleeve	60	3.9	1500	1100	47	36	62	30	2	0.019	1.1	150	510		80		1.2	<5	<5	<5	<5	260
PE168204 R0	MDPZ7467S	5/05/2023	Hydrasleeve	50	7	1400	990	88	45	110	27	0.009	7.4	1.1	130	310		30		<0.05	210	210	250	<5	410
PE168204 R0	MDPZ7467D	5/05/2023	Hydrasleeve	62	7.4	1800	1200	140	63	140	28	<0.005	2.9	0.82	150	380		27		<0.05	330	330	400	<5	620
PE168204 R0	MDPZ7455	5/05/2023	Hydrasleeve	50	3.6	1200	950	60	34	48	39	5.7	26	0.39	81	380	<0.002	77	0.17	<0.05	<5	<5	<5	<5	290
PE168204 R0	MDPZ7459	4/05/2023	Hydrasleeve	20	7.9	690	490	50	27	60	1.9	<0.005	<0.005	<0.001	39	13		94		1.4	300	300	360	<5	240
PE171616	MDP29215S	28/09/2023	Hydrasleeve	20	8	5300	3300	81	130	790	88				1200	690	0.014			4.8	420		520	<1	
PE171616	MDP29215D	28/09/2023	Hydrasleeve	80	7.8	13000	8500	190	330	2000	200				3200	1800	<0.005			1.1	390		480	<1	
PE171616	MDP29223D	30/09/2023	Airlift	Airlift	8.1	8900	5700	150	200	1400	120				2200	1200	<0.005			3.7	390		470	<1	
PE172300	MDPZ9225	5/11/2023	Airlift	Airlift	8.4	2700	1700	55	67	370	36				430	320		68	<0.01	0.01	400	400	490	<1	410
PE172300	MDPZ9224S	30/10/2023	Airlift	Airlift	8.3	4700	2800	50	100	720	46				970	540		87	<0.01	0.028	470	470	570	<1	540
PE172300	MDPB0021 Upper	21/10/2023	Hydrasleeve	67	8.1	6500	4000	80	140	980	97				1500	800		55	<0.01	0.21	400	400	490	<1	770
PE172300	MDPB0021 Lower	21/10/2023	Hydrasleeve	122	8.1	9300	6100	120	230	1500	140				2300	1200		48	<0.01	0.13	400	400	480	<1	1300
PE172300	MDPZ9224D	30/10/2023	Airlift	Airlift	8.1	9100	5800	130	230	1400	120				2300	1100		73	<0.01	<0.005	390	390	480	<1	1300
PE172300	MDPZ9223S	21/10/2023	Hydrasleeve	28	8.1	3200	2000	64	130	370	41				610	360		94	<0.01	0.02	440	440	540	<1	700
PE172300	MDPZ9222S	21/10/2023	Hydrasleeve	37	8.1	5000	3100	91	96	770	53				980	720		66	<0.01	0.01	460	460	560	<1	620
PE172300	MDPB0022	10/10/2023	Airlift	Airlift	8.3	8600	5400	140	220	1300	110				2200	1100		74	<0.01	<0.005	390	390	480	<1	1200
PE172208.001	MDPZ7457_DUP	12/11/2023	Hydrasleeve	28	7.9	7300	4600	120	140		120	0.007	0.007	0.003	1800	960	0.059	76	0.03	3.9	390	390	470	<1	890
PE172208.002	MDPZ7469A	12/11/2023	Hydrasleeve	100	7.1	16000	9600	190	360		270	<0.025	3.7	3.9	4200	2200		16	0.04	<0.05	320	320	390	<1	2000
PE172208.003	MDPZ7469B	12/11/2023	Hydrasleeve	75	7.7	3200	1900	90	83		48	<0.005	<0.005	<0.001	690	370		61	0.02	5.9	190	190	240	<1	570
PE172208.004	MDPZ7469C	12/11/2023	Hydrasleeve	35	7.8	2800	1700	88	79		45	<0.005	<0.005	<0.001	590	320		62	<0.01	6.2	210	210	250	<1	550
PE172208.005	MDPZ7470A	12/11/2023	Hydrasleeve	90	7.7	8600	5100	150	180		120	<0.010	<0.010	1	2300	890		53	<0.01	2.3	330	330	400	<1	1100
PE172208.006	MDPZ7470B	12/11/2023	Hydrasleeve	45	7.9	6200	3600	100	110		110	<0.005	<0.005	<0.001	1600	660		79	<0.01	4	350	350	420	<1	710
PE172208.007	MDPZ7470C	12/11/2023	Hydrasleeve	20	7.9	6000	3400	100	110		120	<0.005	<0.005	<0.001	1500	650	0.095	82	0.02	4.5	380	380	460	<1	700
PE172208.008	MDPZ7470C_DUP	12/11/2023	Hydrasleeve	20	7.9	5900	3500	90	99		110	<0.005	<0.005	0.004	1500	640	0.099	82	0.01	4.5	380	380	460	<1	630
PE172208.009	MDPZ7460A	12/11/2023	Hydrasleeve	85	7.8	6200	3400	120	130		82	<0.005	0.7	0.29	1600	650		27	0.04	0.07	300	300	370	<1	840
PE172208.010	MDPZ7460B	12/11/2023	Hydrasleeve	49	7.7	4600	2800	120	110		59	<0.005	0.006	<0.001	1200	480		60	0.01	4.8	210	210	250	<1	760
PE172208.011	MDPZ7460C	12/11/2023	Hydrasleeve	25	7.7	4400	2700	120	110		59	<0.005	<0.005	<0.001	1100	480		65	0.02	4.9	210	210	250	<1	750
PE172208.012	MDPZ7454	12/11/2023	Hydrasleeve	50	7.1	740	450	26	24		28	<0.005	0.008	0.079	70	170		33	0.02	1.3	89	89	110	<1	160
PE172208.013	MDPZ7456A	13/11/2023	Hydrasleeve	105	8	3600	2200	87	99		52	<0.005	<0.005	<0.001	840	390		48	0.01	3.4	230	230	280	<1	620
PE172208.014	MDPZ7456B	13/11/2023	Hydrasleeve	55	7.5	3900	2300	110	96		50	<0.005	<0.005	<0.001	950	420		61	<0.01	5.4	170	170	210	<1	670
PE172208.015	MDPZ7456C	13/11/2023	Hydrasleeve	20	7.6	3100	1900	97	88		49	<0.005	<0.005	<0.001	680	370		74	0.02	5.5	170	170	210	<1	610
PE172208.016	MDPZ9205	13/11/2023	Hydrasleeve	35	7.5	2100	1300	77	61		33	0.01	0.016	0.001	410	290		50	0.02	4.4	150	150	180	<1	440
PE172208.017	MDPZ7465	13/11/2023	Hydrasleeve	90	7.1	1600	920	38	44		15	<0.005	25	0.25	420	<1	<0.005	41	0.21	<0.05	140	140	180	<1	280
PE172208.018	MDPZ7465_DUP	13/11/2023	Hydrasleeve	90	7	1600	950	38	44		15	<0.005	40	0.28	420	<1	<0.005	41	0.22	<0.05	170	170	200	<1	280
PE172208.019	MDPZ7466S	14/11/2023	Hydrasleeve	40	6.5	300	210	7.8	10		8.2	0.007	0.009	0.001	46	15		57	0.01	5	40	40	49	<1	62
PE172208.020	MDPZ7466D	14/11/2023	Hydrasleeve	60	4	1500	1100	89	69		54	5.3	0.12	2.5	150	540		76	<0.01	1.2	<5	<5	<5	<1	510
PE172208.021	MDPZ7449C	13/11/2023	Hydrasleeve	9	7.7	4500	3000	85	99		24	<0.005	<0.005	0.002	1000	750	0.059	95	0.02	9.2	170	170	210	<1	620
PE172208.022	MDPZ7449C_DUP	13/11/2023	Hydrasleeve	9	7.7	4500	3000	210	170		58	<0.005	<0.005	<0.001	1000	750	0.091	95	0.03	10	170	170	210	<1	1200
PE172208.023	MDPZ7449A	13/11/2023	Hydrasleeve	65	7.7	1900	1200	120	73		33	<0.005	0.16	0.2	250	330		16	0.04	0.09	400	400	490	<1	610
PE172208.024	MDPZ7449B	13/11/2023	Hydrasleeve	25	7.6	1900	1200	80	66		34	<0.005	0.006	0.001	340	290		68	0.01	6.3	170	170	200	<1	470
PE172208.025	MDPZ7450A	13/11/2023	Hydrasleeve	98	7.6	9300	5800	150	220		150	<0.025	0.035	0.073	2400	1300		28	0.01	1.6	330	330	400	<1	1300
PE172208.026	MDPZ7450B	13/11/2023	Hydrasleeve	35	7.8	1300	790	62	50		13	<0.005	<0.005	0.003	160	150		62	0.02	4.2	330	330	400	<1	360
PE172208.027	MDPZ7450C	13/11/2023	Hydrasleeve	20	8	1500	880	66	53		14	<0.005	0.008	<0.001	330	42		74	0.01	2.4	230	230	280	<1	380
PE172208.028	MDPZ7451A	13/11/2023	Hydrasleeve	105	7.6	23000	16000	290	600		450	<0.025	0.035	2.7	6800	3500		24	0.03	<0.05	380	380	460	<1	3200
PE172208.029	MDPZ7451B	13/11/2023	Hydrasleeve	60	7.9	15000	9800	240	370		260	<0.025	0.032	0.65	4100	2200		44	0.01	0.34	400	400	490	<1	2100
PE172208.030	MDPZ7451C	13/11/2023	Hydrasleeve	20	7.6	3000	1800	79	81		55	<0.005	<0.005	<0.001	640	360		61	0.01	6.1	210	210	260	<1	530
PE172208.031	MDPZ7452A	13/11/2023	Hydrasleeve	70	7.9	13000	8400	200	330		220	<0.025	0.58	0.49	3600	1500		43	0.13	0.3	550	550	670	<1	1800
PE172208.032	MDPZ7452B	13/11/2023	Hydrasleeve	45	8	8100	4900	120	170		130	<0.010	<0.010	<0.002	2000	1000		69	0.01	5.4	430	430	520	<1	1000
PE172208.033	MDPZ7452C	13/11/2023	Hydrasleeve	20	8	6700	4000	96	140		110	<0.010	0.011	<0.002	1600	840		74	0.01	5.5	430	430	530	<1	820
PE172208.034	MDPZ7453A	13/11/2023	Hydrasleeve	65	7.7	22000	14000	330	540		400	0.037	0.062	0.007	6200	3300		64	0.01	1.1	420	420	520	<1	3000
PE172208.035	MDPZ7453B	13/11/2023	Hydrasleeve	40	7.9	16000	11000	300	490		270	<0.025	<0.025	0.006	4100	2700		93	0.02	5.5	390	390	480	<1	2800
PE172208.036	MDPZ7453C	13/11/2023	Hydrasleeve	10	7.8	16000	11000	300	540		270	<0.025	<0.025	<0.005	4300	2600		95	0.02	8	390	390	470	<1	3000
PE172208.037	MDPZ7459	12/11/2023	Hydrasleeve	20	8.1	820	530	54	34		2	0.005	<0.005	0.002	53	13		98	0.01	0.92	370	370	450	<1	270
PE172208.038	MDPZ7463 Upper	12/11/2023	Hydrasleeve	15	7.9	4000	2400	83	92		51	0.009	0.023	0.001	810	550		63	0.01	3.4	380	380	460	<1	590

Lab Report	Bore ID	Sample Date	Sample Type	Sample Depth	pH	Conductivity	Total Dissolved Solids	Calcium - Dissolved	Magnesium - Dissolved	Sodium - Dissolved	Potassium - Dissolved	Aluminium - Dissolved	Iron - Dissolved	Manganese - Dissolved	Chloride	Sulfate	Filterable Reactive Phosphorus	Reactive Silica	Ammonia-N	Nitrate-N	Total Alkalinity	Bicarbonate	Bicarbonate	Carbonate	Hardness
					pH units	uS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg CaCO3/L	mg CaCO3/L	mg HCO3/L	mg CO3/L	mg CaCO3/L
PE172208.039	MDPZ7463 Lower	12/11/2023	Hydrasleeve	80	7.8	7900	4600	100	130		71	<0.005	<0.005	<0.001	2000	1200		51	0.01	2.8	350	350	430	<1	770
PE172208.040	MDPZ7464 Upper	12/11/2023	Hydrasleeve	15	8.1	1200	700	34	32		19	<0.005	0.079	<0.001	130	130		64	0.01	1.2	320	320	390	<1	220
PE172208.041	MDPZ7464 Lower	12/11/2023	Hydrasleeve	80	7.7	16000	9700	98	170		110	0.1	0.12	0.018	4300	2500		23	0.01	0.38	350	350	430	<1	950
PE172208.042	MDPZ9215S	12/11/2023	Hydrasleeve	20	8	5100	3000	63	100		81	<0.005	<0.005	<0.001	1200	650		62	0.01	5.2	390	390	470	<1	570
PE172208.043	MDPZ9217	10/11/2023	Hydrasleeve	30	7.9	7700	4700	160	240		100	0.15	0.21	0.012	2100	1100	0.006	46	0.02	3.7	330	330	400	<1	1400
PE172208.044	MDPZ9218	11/11/2023	Hydrasleeve	30	7.9	5800	3400	120	180		75	0.009	0.08	0.58	1400	730	0.027	37	0.5	1.9	320	320	390	<1	1100
PE172208.045	MDPZ9219	9/11/2023	Hydrasleeve	30	8.1	3700	2300	100	120		45	0.011	0.021	0.002	860	430	<0.005	53	0.02	2.3	300	300	370	<1	770
PE172208.046	MDPZ9220	9/11/2023	Hydrasleeve	30	8.1	2400	1400	82	94		35	0.023	1.5	0.027	480	270	<0.005	31	0.03	0.62	290	290	360	<1	590
PE172208.047	MDPZ9221	9/11/2023	Hydrasleeve	30	8.1	3700	2400	110	130		46	0.009	0.029	0.004	830	440	<0.005	64	0.02	3.6	330	330	400	<1	810
PE172208.048	MDPZ9219	9/11/2023	Hydrasleeve	30	8.1	3800	2400	110	120		46	0.006	0.011	0.001	870	430	<0.005	53	0.03	2.4	310	310	370	<1	780
PE172208.049	MD5461	10/11/2023	Hydrasleeve	50	8	2900	1700	77	82		41	<0.005	0.071	0.022	600	340	0.015	58	0.03	6.1	250	250	300	<1	530
PE172208.050	MD5461 DUP	10/11/2023	Hydrasleeve	50	8	2900	1800	63	65		33	0.008	0.045	0.016	610	340	0.03	58	0.03	4.6	260	260	320	<1	430
PE172208.051	MD5382	10/11/2023	Hydrasleeve	45	7.9	1800	1300	160	88		20	<0.005	0.31	0.8	190	400	<0.005	40	0.03	1	370	370	460	<1	760
PE172208.052	MD6605 Upper	10/11/2023	Hydrasleeve	55	7.7	1300	860	100	43		28	<0.005	<0.005	0.055	150	290	<0.005	33	0.03	0.9	190	190	240	<1	430
PE172208.053	MDPZ7461	12/11/2023	Hydrasleeve	20	8	6300	3600	110	150		89	0.026	<0.010	0.003	1600	730		72	0.03	6.1	380	380	460	<1	910
PE172208.054	MDPZ9212S	12/11/2023	Hydrasleeve	20	8.2	15000	8900	130	350		270	0.11	<0.025	<0.005	4100	1900		78	0.26	3.9	440	440	540	<1	1800
PE172208.055	MDPZ9212D	12/11/2023	Hydrasleeve	105	7.9	17000	10000	210	430		270	<0.025	0.046	0.37	5100	2400		38	0.01	1.3	420	420	510	<1	2300
PE172208.056	MDPZ9211	12/11/2023	Hydrasleeve	48	7.9	11000	6500	160	260		180	<0.025	<0.025	<0.005	3000	1400		51	0.01	5	420	420	510	<1	1500
PE172208.057	MDPZ7458A	12/11/2023	Hydrasleeve	68	7.9	13000	7900	180	300		210	<0.025	0.029	0.093	3800	1800		43	0.01	3.8	420	420	510	<1	1700
PE172208.058	MDPZ7458B	12/11/2023	Hydrasleeve	50	7.9	14000	8900	180	310		230	<0.025	<0.025	<0.005	4100	1800		51	0.04	3	440	440	540	<1	1700
PE172208.059	MDPZ7458C	12/11/2023	Hydrasleeve	8	8.2	12000	7000	100	230		200	<0.025	0.029	<0.005	3400	1400		90	0.04	4.9	550	550	670	<1	1200
PE172208.060	MDPZ7457A	12/11/2023	Hydrasleeve	90	7.8	16000	9900	200	360		270	<0.025	<0.025	66	4400	2300		18	0.02	0.47	410	410	500	<1	2000
PE172208.061	MDPZ7457B	12/11/2023	Hydrasleeve	45	7.9	12000	7100	200	220		180	<0.025	<0.025	0.022	2900	1700		62	0.07	0.56	260	260	320	<1	1400
PE172208.062	MDPZ7457C DUP	12/11/2023	Hydrasleeve	28	8.2	7400	4400	130	150		120	<0.025	<0.025	<0.005	1800	1000	0.054	75	0.03	3.8	390	390	480	<1	940
PE172208.063	MDPZ7467S	14/11/2023	Hydrasleeve	50	7.1	1400	900	87	48		26	<0.005	20	1.1	130	320		30	0.08	<0.05	210	210	260	<1	420
PE172208.064	MDPZ7467D	14/11/2023	Hydrasleeve	62	7.5	1800	1300	160	73		32	<0.005	1.5	1	150	410		26	0.09	<0.05	360	360	440	<1	690
PE172208.065	MDPZ7468A	12/11/2023	Hydrasleeve	85	7.8	21000	14000	230	440		310	<0.025	0.27	0.3	6100	3200		18	0.03	0.15	380	380	470	<1	2400
PE172208.066	MDPZ7468B	12/11/2023	Hydrasleeve	60	7.9	15000	9800	200	380		270	<0.025	<0.025	<0.005	3900	2300		49	0.01	2.3	360	360	440	<1	2100
PE172208.067	MDPZ7468C	12/11/2023	Hydrasleeve	30	8.1	10000	6100	160	260		170	0.03	0.23	<0.005	2500	1600		47	0.01	3.4	310	310	380	<1	1500
PE172208.068	MDPZ7471A	12/11/2023	Hydrasleeve	72	8.1	8900	5300	120	220		130	<0.025	<0.025	0.008	2200	1200		65	0.01	4.1	410	410	500	<1	1200
PE172208.070	MDPZ7471C	12/11/2023	Hydrasleeve	15	8.3	7400	4200	88	170		92	0.012	0.19	0.003	1800	900		78	0.01	4.3	420	420	510	<1	910
PE172208.071	MDPZ9213	13/11/2023	Hydrasleeve	40	8.1	2100	1300	85	100		23	0.027	0.054	0.007	320	240		64	0.01	6.4	390	390	470	<1	630
PE172208.072	MDPZ9214	13/11/2023	Hydrasleeve	40	8.1	5200	3000	68	130		74	<0.005	<0.005	0.001	1200	630		87	0.01	3.9	430	430	530	<1	700
PE172208.073	MDPZ9215D	12/11/2023	Hydrasleeve	80	8.1	8700	5100	130	230		130	<0.025	0.037	0.6	2200	1200		52	0.01	2.3	410	410	500	<1	1300
PE172208.074	MDPZ9216	14/11/2023	Hydrasleeve	90	7.8	19000	13000	310	630		320	<0.025	0.06	1.3	5700	3100		25	0.03	0.12	360	360	440	<1	3400
PE172208.075	MDPZ9218	10/11/2023	Hydrasleeve	30	8.1	5700	3400	120	180		74	<0.005	0.41	0.81	1400	750	0.068	39	0.41	2	320	320	390	<1	1100

DETAILED WATER QUALITY ANALYSIS – GROUNDWATER

Detailed Water Quality Analysis – Groundwater

Lab Report	Bore ID	Sample Date	Sample Type	Sample Depth	Ammonium, NH4	Nitrite-N	Fluoride by ISE	Silicon, Si-Dissolved	Sulfur, S	Iron - Total	Aluminium - Total	Mercury - Total	Manganese - Total	Arsenic, As-Dissolved	Boron, B-Dissolved	Beryllium, Be-Dissolved	Barium, Ba-Dissolved	Cadmium, Cd-Dissolved	Cobalt, Co-Dissolved	Chromium, Cr-Dissolved	Copper, Cu-Dissolved	Molybdenum, Mo-Dissolved	Nickel, Ni-Dissolved	Lead, Pb-Dissolved	Total Suspended Solids (TSS)
					mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
19-13311	MD5382	4/08/2019	Airlift																						
19-19847	MD5382	18/11/2019	Hydrasleeve	45																					
20-08048	MD5382	4/05/2020	Hydrasleeve	45						2.3	0.5	<0.0002	0.14												
PE157321	MD5382	12/12/2021	Hydrasleeve	45	0.02			26	30																
PE161850	MD5382	5/07/2022	Hydrasleeve	45		<0.2	0.6	27	32					<0.001	0.33	<0.001	0.038	<0.0001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	130
PE164581	MD5382	23/10/2022	Hydrasleeve	45		<0.2	0.7	17	160					<0.001	0.41	<0.001	0.068	<0.0001	0.003	<0.001	<0.001	<0.001	0.007	<0.001	45
PE168102 R0	MD5382	3/05/2023	Hydrasleeve	45		<0.05	0.7	21	120					<0.001	0.27	<0.001	0.074	<0.0001	0.001	<0.001	<0.001	<0.001	0.003	<0.001	
PE172208.051	MD5382	10/11/2023	Hydrasleeve	45	0.04	<0.05	0.7	19	140					<0.001	0.370	<0.001	0.080	<0.0001	0.001	<0.001	<0.001	<0.001	0.003	<0.001	
19-13311	MD5455	3/08/2019	Airlift																						
19-19847	MD5455	18/11/2019	Hydrasleeve	68																					
19-13311	MD5461	3/08/2019	Airlift																						
19-19847	MD5461	18/11/2019	Hydrasleeve	65																					
20-08048	MD5461	4/05/2020	Hydrasleeve	65						0.95	0.2	<0.0002	0.01												
PE157321	MD5461	12/12/2021	Hydrasleeve	50	<0.02			26	120																
PE161850	MD5461	5/07/2022	Hydrasleeve	65		<0.2	0.3	25	110					<0.001	0.62	<0.001	0.031	<0.0001	<0.001	0.005	<0.001	<0.001	<0.001	<0.001	25
PE164581	MD5461	23/10/2022	Hydrasleeve	50		<0.2	0.8	29	120					<0.001	0.72	<0.001	0.028	<0.0001	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	<5
PE168102 R0	MD5461	3/05/2023	Hydrasleeve	50	0.07	<0.05	0.7	26	120					<0.001	0.42	<0.001	0.050	<0.0001	<0.001	0.004	<0.001	<0.001	<0.001	<0.001	
PE172208.049	MD5461	10/11/2023	Hydrasleeve	50	0.04	<0.05	0.7	27	120					<0.001	0.510	<0.001	0.056	<0.0001	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	
PE172208.050	MD5461 DUP	10/11/2023	Hydrasleeve	50	0.04	<0.05	0.7	22	99					<0.001	0.420	<0.001	0.048	<0.0001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	
19-13311	MD6605	4/08/2019	Airlift																						
19-19847	MD6605 Lower	18/11/2019	Hydrasleeve	85																					
20-08048	MD6605 Lower	4/05/2020	Hydrasleeve	85						17	0.2	0.0043	1.2												
PE157321	MD6605 Lower	12/12/2021	Hydrasleeve	85	0.04			9.9	130																
19-19847	MD6605 Upper	18/11/2019	Hydrasleeve	55																					
20-08048	MD6605 Upper	4/05/2020	Hydrasleeve	55						38,000	100	0.0002	94												
PE157321	MD6605 Upper	12/12/2021	Hydrasleeve	55	<0.02			14	91																
PE172208.052	MD6605 Upper	10/11/2023	Hydrasleeve	55	0.04	<0.05	1.1	15	100					<0.001	0.370	<0.001	0.028	<0.0001	<0.001	0.003	<0.001	<0.001	0.004	<0.001	
PE171616	MDP29215D	28/09/2023	Hydrasleeve	80		0.11	1.7							<0.002				<0.002		<0.002	<0.002		<0.002	<0.002	
PE171616	MDP29215S	28/09/2023	Hydrasleeve	20		<0.005	1.1							0.002				<0.001		0.005	<0.001		<0.001	<0.001	
PE171616	MDP29223D	30/09/2023	Hydrasleeve	Airlift		0.012	1.0							<0.002				<0.002		0.004	<0.002		<0.002	<0.002	
19-16376	MDPB0011	19/09/2019	Pumping Test																						
19-07588	MDPB0012	8/05/2019	Airlift																						
19-16376	MDPB0012	24/09/2019	Pumping Test																						
19-07588	MDPB0013	16/05/2019	Airlift																						
19-17181	MDPB0013	30/09/2019	Pumping Test																						
19-17181	MDPB0014	9/10/2019	Pumping Test																						
19-15185	MDPB0015	9/09/2019	Pumping Test																						
PE154462	MDPB0016	23/08/2021	Airlift			<0.2	0.8	27	120					<0.001	0.61	<0.001	0.014	<0.0001	<0.001	0.003	<0.001	<0.001	0.001	<0.001	98
PE157146	MDPB0016	30/11/2021	Pumping Test (layflat)		<0.02			29	130																
PE154462	MDPB0017	23/08/2021	Airlift			<0.2	0.7	24	120					<0.001	0.51	<0.001	0.015	<0.0001	<0.001	0.001	<0.001	<0.001	0.002	<0.001	29
PE155569	MDPB0017	13/10/2021	Pumping Test			<0.2	0.7	26	140					<0.001	0.4	<0.001	0.016	<0.0001	<0.001	0.004	<0.001	<0.001	0.002	<0.001	<5
PE154462	MDPB0018	4/09/2021	Airlift			<0.2	0.9	13	140					0.002	0.48	<0.001	0.016	0.0002	0.007	<0.001	<0.001	<0.001	0.02	<0.001	86
PE155297	MDPB0018	30/09/2021	Pumping Test - End			<0.2	0.8	20	98					<0.001	0.42	<0.001	0.017	0.0001	0.004	<0.001	0.003	<0.001	0.016	<0.001	<5
PE155018	MDPB0019	10/09/2021	Airlift			<0.2	0.7	18	56					<0.001	0.3	<0.001	0.005	0.0002	<0.001	<0.001	<0.001	<0.001	0.005	<0.001	10
PE155569	MDPB0019	8/10/2021	Pumping Test			<0.2	0.6	22	38					<0.001	0.26	<0.001	<0.001	0.0003	<0.001	<0.001	0.001	<0.001	0.004	<0.001	<5
PE156870	MDPB0020	12/11/2021	Airlift			<0.2	3.2	20	780					<0.005	3.1	<0.005	<0.005	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	13
PE157146	MDPB0020	5/12/2021	Pumping Test		<0.02			21	560																
PE157146	MDPB0020	9/12/2021	Pumping Test		<0.02			24	750																
PE172300	MDPB0021 Upper	21/10/2023	Hydrasleeve	67	<0.02	3.4	1.4							<0.001				<0.001		<0.001	0.002		0.220	<0.001	
PE172300	MDPB0021 Lower	21/10/2023	Hydrasleeve	122	<0.02	2.9	1.7							<0.002				<0.002		<0.002	<0.002		0.150	<0.002	
PE172300	MDPB0022	10/10/2023	Airlift	Airlift	<0.02	4.1	1.1							<0.002				<0.002		0.004	<0.002		<0.002	<0.002	
PE071720	MDPB004	7/10/2012	Pumping Test				0.6	29		<0.02															
PE071720	MDPB004	8/10/2012	Pumping Test				0.6	30		<0.02		<0.0001		<0.02				<0.005		<0.005	0.012		<0.005	<0.005	
PE071585	MDPB005	1/10/2012	Pumping Test				0.5	24		<0.02		<0.0001		<0.02				<0.005		<0.005	0.016		0.006	<0.005	
PE071585	MDPB005	2/10/2012	Pumping Test				0.5	25		<0.02		<0.0001		<0.02				<0.005		<0.005	0.01		0.007	<0.005	
PE071720	MDPB006	4/10/2012	Pumping Test				0.6	25		0.19															
PE071720	MDPB006	5/10/2012	Pumping Test				0.6	25		0.21		<0.0001		<0.02				<0.005		<0.005	0.006		0.038	<0.005	
19-08491	MDPZ7449A	31/05/2019	Airlift																						
19-19847	MDPZ7449A	16/11/2019	Hydrasleeve	65																					
20-08048	MDPZ7449A	2/05/2020	Hydrasleeve	65						2.6	0.6	<0.0002	0.33												
21-05186	MDPZ7449A	17/03/2021	Hydrasleeve	65																					
21-19363	MDPZ7449A	16/10/2021	Hydrasleeve	65																					
PE157146	MDPZ7449A	7/12/2021	Hydrasleeve	65	1.1			7.4	110																
PE161850	MDPZ7449A	6/07/2022	Hydrasleeve	65		<0.2	0.9	6.6	110					0.004	0.46	<0.001	0.017	<0.0001	<0.001	<0.001	<0.001	<0.001	0.005	<0.001	110
PE164581	MDPZ7449A	26/10/2022	Hydrasleeve	65		<0.2	1	7.6	110					0.003	0.52	<0.001	0.016	<0.0001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	55
PE168204 R0	MDPZ7449A	4/05/2023	Hydrasleeve	65		<0.05	1.0	6.8	110					0.006	0.44	<0.001	0.039	<0.0001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	
PE172208.023	MDPZ7449A	13/11/2023	Hydrasleeve	65	0.06	<0.05	0.9	7.4	120					0.004	0.420	<0.001	0.030	<0.0001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	
19-04258	MDPZ7449B	18/03/2019	Airlift																						
19-19847	MDPZ7449B	16/11/2019	Hydrasleeve	25																					
20-08048	MDPZ7449B	2/05/2020	Hydrasleeve	25						2.7	0.7	<0.0002	0.07												
21-05186	MDPZ7449B	17/03/2021	Hydrasleeve	25																					
21-19363	MDPZ7449B	16/10/2021	Hydrasleeve	25																					
PE157146	MDPZ7449B	7/12/2021	Hydrasleeve	25	0.07			30	96																
PE161850	MDPZ7449B	6/07/2022	Hydrasleeve	25		<0.2	0.7	27	100					<0.001	0.46	<0.001	0.041	<0.0001	<0.001	0.005	<0.001	<0.001	0.002	<0.001	44
PE164581	MDPZ7449B	26/10/2022	Hydrasleeve	25		<0.2	0.7	32	110					<0.001	0.5	<0.001	0.035	<0.0001	<0.001	0.004	<0.001	<0.001	0.001	<0.001	8
PE168204 R0	MDPZ7449B	4/05/2023	Hydrasleeve	25		<0.05	0.7	29	90					<0.001	0.44	<0.001	0.054	<0.0001	<0.001	0.004	<0.001	<0.001	0.001	<0.001	
PE172208.024	MDPZ7449B	13/11/2023	Hydrasleeve	25	<0.02	<0.05	0.7	31	100					<0.001	0.430	<0.001	0.059	<0.0001	<0.001	0.005	<0.001	<0.001	0.002	<0.001	
19-13311	MDPZ7449C	11/08/2019	Airlift																						
19-19847	MDPZ7449C	16/11/2019	Hydrasleeve	9																					
20-08048	MDPZ7449C	2/05/2020	Hydrasleeve	9						9.8	3.1	<0.0002	0.19												
21-05186	MDPZ7449C	17/03/2021	Hydrasleeve	9																					
21-19363	MDPZ7449C	16/10/2021	Hydrasleeve	9																					
PE157146	MDPZ7449C	7/12/2021	Hydrasleeve	9	0.02			43	330																
PE161850	MDPZ7449C	6/07/2022	Hydrasleeve	9		<0.2	0.7	41	340					0.001	0.68	<0.001	0.056	<0.0001	<0.001	0.012	<0.001	<0.001	<0.001	<0.001	250
PE164581	MDPZ7449C	26/10/2022	Hydrasleeve	9		<0.2	0.6	45	310					<0.001	0.7	<0.001	0.045	<0.0001	<0.001	0.008	<0.001	<0.001	<0.001	<0.001	73
PE168204 R0	MDPZ7449C	4/05/2023	Hydrasleeve	9	<0.02	<0.05	0.7	40	240					<0.001	0.46	<0.001	0.051	<0.0001	<0.001	0.007	<0.001	<0.001	<0.001	<0.001	
PE172208.021	MDPZ7449C	13/11/2023	Hydrasleeve	9	0.02	<0.05	0.6	29	90					<0.001	0.400	<0.001	0.036	<0.0001	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	
PE172208.022	MDPZ7449C_DUP	13/11/2023	Hydrasleeve	9	0.03	<0.05	0.6	44	270					0.001	0.480	<0.001	0.056	<0.0001	<0.001	0.007	<0.001	<0.001	<0.001	<0.001	
19-08491	MDPZ7450A	30/05/2019	Airlift																						
19-19847	MDPZ7450A	18/11/2019	Hydrasleeve	98																					
20-08048	MDPZ7450A	2/05/2020	Hydrasleeve	98						4.5	0.9	<0.0002	0.3												
21-05186	MDPZ7450A	17/03/2021	Hydrasleeve	98																					
21-19363	MDPZ7450A	16/10/2021	Hydrasleeve	98																					
PE157146	MDPZ7450A	7/12/2021	Hydrasleeve	98	0.06			15	530																
PE161850	MDPZ7450A	6/07/2022	Hydrasleeve	98		<0.2	2.2	8.6	780					<0.005	3.2	<0.005	0.009	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	24
PE164581	MDPZ7450A	22/10/2022	Hydrasleeve	98		<0.2	1.6	10	680					<0.005	2.7	<0.005	0.007	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	36
PE168204 R0	MDPZ7450A	4/05/2023	Hydrasleeve	98		0.16	2.1	16	470					<0.002	1.70	<0.002	0.026	<0.0002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	
PE172208.025	MDPZ7450A	13/11/2023	Hydrasleeve	98	<0.02	<0.05	1.5	14	520					<0.005	2.000	<0.005	0.011	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	

Lab Report	Bore ID	Sample Date	Sample Type	Sample Depth	Ammonium, NH4	Nitrite-N	Fluoride by ISE	Silicon, Si-Dissolved	Sulfur, S	Iron - Total	Aluminium - Total	Mercury - Total	Manganese - Total	Arsenic, As-Dissolved	Boron, B-Dissolved	Beryllium, Be-Dissolved	Barium, Ba-Dissolved	Cadmium, Cd-Dissolved	Cobalt, Co-Dissolved	Chromium, Cr-Dissolved	Copper, Cu-Dissolved	Molybdenum, Mo-Dissolved	Nickel, Ni-Dissolved	Lead, Pb-Dissolved	Total Suspended Solids (TSS)
					mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
19-08491	MDPZ7450B	29/05/2019	Airlift																						
19-19847	MDPZ7450B	16/11/2019	Hydrasleeve	35																					
20-08048	MDPZ7450B	2/05/2020	Hydrasleeve	35						15	5.4	<0.0002	0.16												
21-05186	MDPZ7450B	17/03/2021	Hydrasleeve	35																					
21-19363	MDPZ7450B	16/10/2021	Hydrasleeve	35																					
PE157146	MDPZ7450B	7/12/2021	Hydrasleeve	35	0.05			28	51																
PE161850	MDPZ7450B	6/07/2022	Hydrasleeve	35		<0.2	1	25	50					<0.001	0.51	<0.001	0.055	<0.0001	<0.001	0.003	<0.001	0.002	<0.001	<0.001	540
PE164581	MDPZ7450B	22/10/2022	Hydrasleeve	35		<0.2	1	31	60					<0.001	0.45	<0.001	0.046	<0.0001	<0.001	0.003	<0.001	0.001	<0.001	<0.001	150
PE168204 R0	MDPZ7450B	4/05/2023	Hydrasleeve	35		<0.05	1.0	25	49					<0.001	0.42	<0.001	0.082	<0.0001	<0.001	0.002	<0.001	0.001	<0.001	<0.001	
PE172208.026	MDPZ7450B	13/11/2023	Hydrasleeve	35	<0.02	<0.05	1.0	28	52					<0.001	0.390	<0.001	0.068	<0.0001	<0.001	0.003	<0.001	0.002	<0.001	<0.001	
19-08491	MDPZ7450C	27/05/2019	Airlift																						
19-19847	MDPZ7450C	16/11/2019	Hydrasleeve	20																					
20-08048	MDPZ7450C	2/05/2020	Hydrasleeve	20						11	5.2	<0.0002	0.23												
21-05186	MDPZ7450C	17/03/2021	Hydrasleeve	20																					
21-19363	MDPZ7450C	16/10/2021	Hydrasleeve	20																					
PE157146	MDPZ7450C	7/12/2021	Hydrasleeve	20	<0.02			32	12																
PE161850	MDPZ7450C	6/07/2022	Hydrasleeve	20		<0.2	1.2	28	12					0.001	0.44	<0.001	0.17	<0.0001	<0.001	0.004	<0.001	0.003	<0.001	<0.001	300
PE164581	MDPZ7450C	22/10/2022	Hydrasleeve	20		<0.2	1.2	32	15					<0.001	0.4	<0.001	0.15	<0.0001	<0.001	0.004	<0.001	0.002	<0.001	<0.001	140
PE168102 R0	MDPZ7450C	4/05/2023	Hydrasleeve	20		<0.05	1.1	31	11					0.001	0.22	<0.001	0.340	<0.0001	<0.001	0.003	<0.001	0.002	<0.001	<0.001	
PE172208.027	MDPZ7450C	13/11/2023	Hydrasleeve	20	<0.02	<0.05	0.3	34	14					0.001	0.300	<0.001	0.430	<0.0001	<0.001	0.004	<0.001	0.002	<0.001	<0.001	
19-12584	MDPZ7451A	17/07/2019	Airlift																						
19-19847	MDPZ7451A	16/11/2019	Hydrasleeve	105																					
20-08048	MDPZ7451A	2/05/2020	Hydrasleeve	105						20	2.9	<0.0002	4												
21-14674	MDPZ7451A	4/08/2021	Hydrasleeve	105																					
PE157146	MDPZ7451A	5/12/2021	Hydrasleeve	105	0.1			14	1200																
PE161850	MDPZ7451A	6/07/2022	Hydrasleeve	105		<0.2	2.9	12	1300					<0.005	4.9	<0.005	0.026	<0.0005	0.01	<0.005	<0.005	<0.005	0.012	<0.005	92
PE164581	MDPZ7451A	22/10/2022	Hydrasleeve	105		<0.2	2.9	13	1400					<0.005	5	<0.005	0.023	0.0011	0.098	<0.005	<0.005	<0.005	0.099	<0.005	1,000
PE168204 R0	MDPZ7451A	4/05/2023	Hydrasleeve	105		<0.05	2.9	12	1300					<0.005	4.70	<0.005	0.032	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
PE172208.028	MDPZ7451A	13/11/2023	Hydrasleeve	105	0.04	<0.05	2.8	12	1300					<0.005	5.000	<0.005	0.035	<0.0005	<0.005	<0.005	<0.005	<0.005	0.005	<0.005	
19-04258	MDPZ7451B	17/03/2019	Airlift																						
19-19847	MDPZ7451B	16/11/2019	Hydrasleeve	60																					
20-08048	MDPZ7451B	2/05/2020	Hydrasleeve	60						8.6	2.9	<0.0002	1.3												
21-14674	MDPZ7451B	4/08/2021	Hydrasleeve	60																					
PE157146	MDPZ7451B	5/12/2021	Hydrasleeve	60	0.04			25	780																
PE161850	MDPZ7451B	6/07/2022	Hydrasleeve	60		0.3	1.6	27	850					<0.005	3.4	<0.005	0.051	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	53
PE164581	MDPZ7451B	22/10/2022	Hydrasleeve	60		0.3	1.6	26	870					<0.005	3.3	<0.005	0.043	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	45
PE168204 R0	MDPZ7451B	4/05/2023	Hydrasleeve	60		0.07	4.6	22	800					<0.005	2.50	<0.005	0.052	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
PE172208.029	MDPZ7451B	13/11/2023	Hydrasleeve	60	<0.02	<0.05	1.5	21	870					<0.005	3.100	<0.005	0.064	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
19-04258	MDPZ7451C	17/03/2019	Airlift																						
19-19847	MDPZ7451C	16/11/2019	Hydrasleeve	20																					
20-08048	MDPZ7451C	2/05/2020	Hydrasleeve	20						15	6.9	0.0003	0.27												
21-14674	MDPZ7451C	4/08/2021	Hydrasleeve	20																					
PE157146	MDPZ7451C	5/12/2021	Hydrasleeve	20	0.03			29	130																
PE161850	MDPZ7451C	6/07/2022	Hydrasleeve	20		<0.2	1	25	130					<0.001	0.72	<0.001	0.033	<0.0001	<0.001	0.006	<0.001	<0.001	<0.001	<0.001	180
PE164581	MDPZ7451C	22/10/2022	Hydrasleeve	20		<0.2	1	30	130					<0.001	0.69	<0.001	0.031	<0.0001	<0.001	0.004	<0.001	<0.001	<0.001	<0.001	110
PE168204 R0	MDPZ7451C	4/05/2023	Hydrasleeve	20		<0.05	1.0	27	130					<0.001	0.79	<0.001	0.045	<0.0001	<0.001	0.004	<0.001	<0.001	<0.001	<0.001	
PE172208.030	MDPZ7451C	13/11/2023	Hydrasleeve	20	<0.02	<0.05	1.0	28	130					<0.001	0.810	<0.001	0.046	<0.0001	<0.001	0.005	<0.001	<0.001	<0.001	<0.001	
19-19847	MDPZ7452A	16/11/2019	Hydrasleeve	70																					
20-08048	MDPZ7452A	3/05/2020	Hydrasleeve	70						2.9	0.2	0.0002	0.09												
21-14674	MDPZ7452A	4/08/2021	Hydrasleeve	70																					
PE157146	MDPZ7452A	5/12/2021	Hydrasleeve	70	<0.02			22	500																
PE161850	MDPZ7452A	6/07/2022	Hydrasleeve	70		<0.2	1.6	20	520					<0.005	2.2	<0.005	0.071	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	6
PE164581	MDPZ7452A	22/10/2022	Hydrasleeve	70		<0.2	1.5	19	510					<0.005	2.1	<0.005	0.07	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	9
PE168204 R0	MDPZ7452A	4/05/2023	Hydrasleeve	70		<0.05	1.5	18	510					<0.005	2.20	<0.005	0.083	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
PE172208.031	MDPZ7452A	13/11/2023	Hydrasleeve	70	0.17	<0.05	1.6	21	560					<0.005	2.100	<0.005	0.084	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
19-04258	MDPZ7452B	17/03/2019	Airlift																						
19-19847	MDPZ7452B	16/11/2019	Hydrasleeve	45																					
20-08048	MDPZ7452B	3/05/2020	Hydrasleeve	45						1.3	0.5	0.0002	0.02												
21-14674	MDPZ7452B	4/08/2021	Hydrasleeve	45																					
PE157146	MDPZ7452B	5/12/2021	Hydrasleeve	45	0.04			33	350																
PE161850	MDPZ7452B	6/07/2022	Hydrasleeve	45		<0.2	1.6	31	360					<0.002	1.4	<0.002	0.011	<0.0002	<0.002	0.005	<0.002	<0.002	<0.002	<0.002	19
PE164581	MDPZ7452B	22/10/2022	Hydrasleeve	45		<0.2	1.6	33	340					<0.002	1.4	<0.002	0.011	<0.0002	<0.002	0.005	<0.002	<0.002	<0.002	<0.002	5
PE168204 R0	MDPZ7452B	4/05/2023	Hydrasleeve	45		<0.05	1.6	31	350					<0.002	1.40	<0.002	0.024	<0.0002	<0.002	0.004	<0.002	<0.002	<0.002	<0.002	
PE172208.032	MDPZ7452B	13/11/2023	Hydrasleeve	45	<0.02	<0.05	<0.1	32	390					<0.002	1.500	<0.002	0.018	<0.0002	<0.002	0.005	<0.002	<0.002	<0.002	<0.002	
19-08491	MDPZ7452C	27/05/2019	Airlift																						
19-19847	MDPZ7452C	16/11/2019	Hydrasleeve	20																					
20-08048	MDPZ7452C	3/05/2020	Hydrasleeve	20						0.09	<0.1	<0.0002	<0.01												
21-14674	MDPZ7452C	4/08/2021	Hydrasleeve	20																					
PE157146	MDPZ7452C	5/12/2021	Hydrasleeve	20	0.08			36	320																
PE161850	MDPZ7452C	6/07/2022	Hydrasleeve	20		<0.2	1.7	32	320					<0.002	1.3	<0.002	0.012	<0.0002	<0.002	0.005	<0.002	<0.002	<0.002	<0.002	<5
PE164581	MDPZ7452C	22/10/2022	Hydrasleeve	20		<0.2	1.5	36	320					<0.001	1.4	<0.001	0.012	<0.0001	<0.001	0.006	<0.001	<0.001	<0.001	<0.001	12
PE168204 R0	MDPZ7452C	4/05/2023	Hydrasleeve	20		<0.05	1.7	32	310					<0.002	1.30	<0.002	0.025	<0.0002	<0.002	0.004	<0.002	<0.002	<0.002	<0.002	
PE172208.033	MDPZ7452C	13/11/2023	Hydrasleeve	20	<0.02	<0.05	1.7	34	320					<0.002	1.300	<0.002	0.017	<0.0002	<0.002	0.005	<0.002	<0.002	<0.002	<0.002	
19-15185	MDPZ7453A	6/09/2019	Airlift																						
19-19847	MDPZ7453A	16/11/2019	Hydrasleeve	65																					
20-08048	MDPZ7453A	3/05/2020	Hydrasleeve	65						0.61	0.2	0.0003	<0.01												
21-14674	MDPZ7453A	4/08/2021	Hydrasleeve	65																					
PE157146	MDPZ7453A	5/12/2021	Hydrasleeve	65	0.1			30	1200																
PE161850	MDPZ7453A	6/07/2022	Hydrasleeve	65		<0.2	3	27	1200					<0.005	4.2	<0.005	0.037	<0.0005	<0.005	0.005	<0.005	0.022	<0.005	<0.005	26
PE164581	MDPZ7453A	22/10/2022	Hydrasleeve	65		<0.2	3.3	30	1200					<0.005	4.6	<0.005	0.038	<0.0005	<0.005	<0.005	<0.005	0.019	<0.005	<0.005	<5
PE168204 R0	MDPZ7453A	4/05/2023	Hydrasleeve	65		<0.05	3.5	28	1200					<0.005	3.90	<0.005	0.025	<0.0005	<0.005	0.007	<0.005	0.021	<0.005	<0.005	
PE172208.034	MDPZ7453A	13/11/2023	Hydrasleeve	65	<0.02	<0.05	4.5	30	1200					<0.005	4.600	<0.005	0.019	<0.0005	<0.005	0.007	<0.005	0.025	<0.005	<0.005	
19-08491	MDPZ7453B	28/05/2019	Airlift																						
19-19847	MDPZ7453B	16/11/2019	Hydrasleeve	40																					
20-08048	MDPZ7453B	3/05/2020	Hydrasleeve	40						0.72	0.3	<0.0002	<0.01												
21-14674	MDPZ7453B	4/08/2021	Hydrasleeve	40																					
PE157146	MDPZ7453B	5/12/2021	Hydrasleeve	40	0.03			46	960																
PE161850	MDPZ7453B	6/07/2022	Hydrasleeve	40		<0.2	2.5	45	980					0.006	3.5	<0.005	0.016	<0.0005	<0.005	0.005	<0.005	0.007	<0.005	<0.005	15
PE164581	MDPZ7453B	22/10/2022	Hydrasleeve	40		<0.2	2.4	45	980					0.006	3.3	<0.005	0.016	<0.0005	<0.005	<0.005	<0.005	0.007	<0.005	<0.005	6
PE168204 R0	MDPZ7453B	4/05/2023	Hydrasleeve	40		<0.05	2.7	42	940					0.008	3.40	<0.005	0.019	<0.0005	<0.005	<0.005	<0.005	0.006	<0.005	<0.005	
PE172208.035	MDPZ7453B	13/11/2023	Hydrasleeve	40	0.03	<0.05	2.5	45	930					0.008	3.400	<0.005	0.021	<0.0005	<0.005	<0.005	<0.005	0.008	<0.005	<0.005	
19-08491	MDPZ7453C	27/05/2019	Airlift																						
19-19847	MDPZ7453C	16/11/2019	Hydrasleeve	10																					
20-08048	MDPZ7453C	3/05/2020	Hydrasleeve	10						0.43	0.2	<0.0002	0.02												
21-14674	MDPZ7453C	4/08/2021	Hydrasleeve	10																					
PE157146	MDPZ7453C	5/12/2021	Hydrasleeve	10	0.04			46	880																
PE161850	MDPZ7453C	6/07/2022	Hydrasleeve	10		<0.2	3.3	46	930					0.011	3.7	<0.005	0.029	<0.0005	<0.005	<0.005	<0.005	0.011	<0.005	<0.005	14
PE164581	MDPZ7453C	22/10/2022	Hydrasleeve	10		<0.2	3.1	47	910					0.01	3.5	<0.005	0.026	<0.0005	<0.005	<0.005	<0.005	0.01	<0.005	<0.005	<5

Lab Report	Bore ID	Sample Date	Sample Type	Sample Depth	Ammonium, NH4	Nitrite-N	Fluoride by ISE	Silicon, Si-Dissolved	Sulfur, S	Iron - Total	Aluminium - Total	Mercury - Total	Manganese - Total	Arsenic, As-Dissolved	Boron, B-Dissolved	Beryllium, Be-Dissolved	Barium, Ba-Dissolved	Cadmium, Cd-Dissolved	Cobalt, Co-Dissolved	Chromium, Cr-Dissolved	Copper, Cu-Dissolved	Molybdenum, Mo-Dissolved	Nickel, Ni-Dissolved	Lead, Pb-Dissolved	Total Suspended Solids (TSS)
					mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
PE168204 R0	MDPZ7453C	4/05/2023	Hydrasleeve	10		<0.05	3.7	43	890					0.012	3.40	<0.005	0.028	<0.0005	<0.005	<0.005	<0.005	0.009	<0.005	<0.005	
PE172208.036	MDPZ7453C	13/11/2023	Hydrasleeve	10	0.02	<0.05	3.4	46	900					0.010	3.600	<0.005	0.033	<0.0005	<0.005	<0.005	<0.005	0.011	<0.005	<0.005	
19-19463	MDPZ7454	10/11/2019	Hydrasleeve	50																					
20-08048	MDPZ7454	4/05/2020	Hydrasleeve	50						120	11	<0.0002	0.81												
21-05186	MDPZ7454	17/03/2021	Hydrasleeve	50																					
21-19363	MDPZ7454	16/10/2021	Hydrasleeve	50																					
PE157146	MDPZ7454	9/12/2021	Hydrasleeve	50	0.7			13	100																
PE161850	MDPZ7454	9/07/2022	Hydrasleeve	50		<0.2	0.7	18	53					<0.001	0.32	<0.001	0.023	0.0002	<0.001	<0.001	<0.001	<0.001	0.02	<0.001	330
PE164581	MDPZ7454	26/10/2022	Hydrasleeve	50		<0.2	0.6	17	69					<0.001	0.42	<0.001	0.025	0.0001	<0.001	<0.001	<0.001	<0.001	0.015	<0.001	660
PE168102 R0	MDPZ7454	4/05/2023	Hydrasleeve	50		<0.05	0.7	18	41					<0.001	0.23	<0.001	0.059	0.0001	0.002	<0.001	<0.001	<0.001	0.013	<0.001	
PE172208.012	MDPZ7454	12/11/2023	Hydrasleeve	50	0.02	<0.05	0.6	15	60					<0.001	0.280	<0.001	0.043	<0.0002	0.003	<0.001	<0.001	<0.001	0.015	<0.001	
19-19847	MDPZ7455	17/11/2019	Hydrasleeve	50																					
20-08048	MDPZ7455	4/05/2020	Hydrasleeve	50						54	11	<0.0002	0.62												
21-05186	MDPZ7455	16/03/2021	Hydrasleeve	50																					
21-19363	MDPZ7455	16/10/2021	Hydrasleeve	50																					
PE157146	MDPZ7455	8/12/2021	Hydrasleeve	50	0.35			37	150																
PE161850	MDPZ7455	10/07/2022	Hydrasleeve	50		<0.2	0.6	34	150					0.032	0.35	0.001	0.003	0.0009	0.038	<0.001	<0.001	<0.001	0.074	<0.001	320
PE164581	MDPZ7455	26/10/2022	Hydrasleeve	50			0.7	36	150																500
PE168204 R0	MDPZ7455	5/05/2023	Hydrasleeve	50	0.21	<0.05	0.6	32	150					0.033	0.32	0.001	0.027	0.0009	0.035	<0.001	<0.001	<0.001	0.070	<0.001	
19-15185	MDPZ7456A	5/09/2019	Airlift																						
19-19847	MDPZ7456A	17/11/2019	Hydrasleeve	105																					
20-08048	MDPZ7456A	4/05/2020	Hydrasleeve	105						13	2.8	<0.0002	8.5												
21-05186	MDPZ7456A	16/03/2021	Hydrasleeve	105																					
PE157146	MDPZ7456A	7/12/2021	Hydrasleeve	105	<0.02			22	140																
PE161850	MDPZ7456A	9/07/2022	Hydrasleeve	105		<0.2	0.7	20	140					0.001	0.47	<0.001	0.027	<0.0001	<0.001	<0.001	<0.001	0.005	<0.001	<0.001	53
PE164581	MDPZ7456A	26/10/2022	Hydrasleeve	105			0.7	23	140																44
PE168204 R0	MDPZ7456A	5/05/2023	Hydrasleeve	105		<0.05	0.7	21	140					<0.001	0.53	<0.001	0.037	<0.0001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	
PE172208.013	MDPZ7456A	13/11/2023	Hydrasleeve	105	<0.02	<0.05	0.7	22	130					0.001	0.360	<0.001	0.036	<0.0001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	
19-08491	MDPZ7456B	29/05/2019	Airlift																						
19-19847	MDPZ7456B	17/11/2019	Hydrasleeve	55																					
20-08048	MDPZ7456B	4/05/2020	Hydrasleeve	55						1.8	0.4	<0.0002	0.22												
21-05186	MDPZ7456B	16/03/2021	Hydrasleeve	55																					
PE157146	MDPZ7456B	7/12/2021	Hydrasleeve	55	<0.02			29	150																
PE161850	MDPZ7456B	9/07/2022	Hydrasleeve	55		<0.2	0.7	27	150					<0.001	0.49	<0.001	0.003	<0.0001	<0.001	0.005	<0.001	<0.001	<0.001	<0.001	20
PE164581	MDPZ7456B	26/10/2022	Hydrasleeve	55			0.6	29	150																9
PE168204 R0	MDPZ7456B	5/05/2023	Hydrasleeve	55		<0.05	0.7	26	150					<0.001	0.54	<0.001	0.029	<0.0001	<0.001	0.004	<0.001	<0.001	0.001	<0.001	
PE172208.014	MDPZ7456B	13/11/2023	Hydrasleeve	55	<0.02	<0.05	0.6	27	160					<0.001	0.330	<0.001	0.020	<0.0001	<0.001	0.004	<0.001	<0.001	0.001	<0.001	
19-08491	MDPZ7456C	27/05/2019	Airlift																						
19-19847	MDPZ7456C	17/11/2019	Hydrasleeve	20																					
20-08048	MDPZ7456C	4/05/2020	Hydrasleeve	20						37	10	<0.0002	3.2												
21-05186	MDPZ7456C	16/03/2021	Hydrasleeve	20																					
PE157146	MDPZ7456C	7/12/2021	Hydrasleeve	20	0.03			38	130																
PE161850	MDPZ7456C	9/07/2022	Hydrasleeve	20		<0.2	0.8	34	140					<0.001	0.74	<0.001	0.043	<0.0001	<0.001	0.01	<0.001	<0.001	<0.001	<0.001	180
PE164581	MDPZ7456C	26/10/2022	Hydrasleeve	20			0.8	35	140																40
PE168204 R0	MDPZ7456C	5/05/2023	Hydrasleeve	20		<0.05	1.0	35	150					<0.001	0.92	<0.001	0.053	<0.0001	<0.001	0.008	<0.001	<0.001	<0.001	<0.001	
PE172208.015	MDPZ7456C	13/11/2023	Hydrasleeve	20	0.02	<0.05	0.8	31	140					<0.001	0.400	<0.001	0.042	<0.0001	<0.001	0.009	<0.001	<0.001	<0.001	<0.001	
PE172208.001	MDPZ7457_DUP	12/11/2023	Hydrasleeve	28	0.04	0.06	1.5	35	360					0.002	1.800	<0.001	0.040	<0.0001	<0.001	0.021	<0.001	0.001	<0.001	<0.001	
19-04258	MDPZ7457A	13/03/2019	Airlift																						
19-19463	MDPZ7457A	13/11/2019	Hydrasleeve	90																					
20-08048	MDPZ7457A	2/05/2020	Hydrasleeve	90						1.3	0.4	<0.0002	1.1												
21-14674	MDPZ7457A	4/08/2021	Hydrasleeve	90																					
PE157146	MDPZ7457A	2/12/2021	Hydrasleeve	90	0.03			9.1	760																
PE161850	MDPZ7457A	7/07/2022	Hydrasleeve	90		<0.2	2.6	8.7	730					<0.005	3.2	<0.005	<0.005	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	11
PE164581	MDPZ7457A	26/10/2022	Hydrasleeve	90		<0.2	2.5	8.7	800					<0.005	2.9	<0.005	<0.005	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	6
PE168204 R0	MDPZ7457A	4/05/2023	Hydrasleeve	90		<0.05	2.7	7.8	740					<0.005	2.80	<0.005	0.007	<0.0005	<0.005	<0.005	<0.001	<0.005	<0.005	<0.005	
PE172208.060	MDPZ7457A	12/11/2023	Hydrasleeve	90	0.02	<0.05	2.6	9.1	700					<0.005	3.100	<0.005	0.009	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
19-04258	MDPZ7457B	14/03/2019	Airlift																						
19-19463	MDPZ7457B	13/11/2019	Hydrasleeve	45																					
20-08048	MDPZ7457B	2/05/2020	Hydrasleeve	45						0.94	0.3	<0.0002	0.04												
21-14674	MDPZ7457B	4/08/2021	Hydrasleeve	45																					
PE157146	MDPZ7457B	2/12/2021	Hydrasleeve	45	0.09			30	610																
PE161850	MDPZ7457B	7/07/2022	Hydrasleeve	45		0.4	1.4	27	610					<0.005	2.1	<0.005	0.083	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<5
PE164581	MDPZ7457B	26/10/2022	Hydrasleeve	45		<0.2	1.5	30	640					<0.005	2.1	<0.005	0.047	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	5
PE168204 R0	MDPZ7457B	5/05/2023	Hydrasleeve	45		<0.05	1.6	26	630					<0.002	2.00	<0.002	0.067	<0.0002	<0.002	<0.002	<0.002	0.003	<0.002	<0.002	
PE172208.061	MDPZ7457B	12/11/2023	Hydrasleeve	45	0.09	<0.05	1.5	30	550					<0.005	2.200	<0.005	0.049	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
19-04258	MDPZ7457C	16/03/2019	Airlift																						
19-19463	MDPZ7457C	13/11/2019	Hydrasleeve	28																					
20-08048	MDPZ7457C	2/05/2020	Hydrasleeve	28						2.4	0.9	<0.0002	0.07												
21-14674	MDPZ7457C	4/08/2021	Hydrasleeve	28																					
PE157146	MDPZ7457C	2/12/2021	Hydrasleeve	28	<0.02			36	350																
PE161850	MDPZ7457C	7/07/2022	Hydrasleeve	28		<0.2	1	34	370					0.002	1.7	<0.002	0.043	<0.0002	<0.002	0.025	<0.002	<0.002	<0.002	<0.002	13
PE164581	MDPZ7457C	26/10/2022	Hydrasleeve	28		0.2	1.6	36	350					0.002	1.6	<0.001	0.041	<0.0001	<0.001	0.019	<0.001	0.002	<0.001	<0.001	<5
PE168204 R0	MDPZ7457C	5/05/2023	Hydrasleeve	28	1300	0.08	1.6	33	380					0.002	1.70	<0.002	0.038	<0.0002	<0.002	0.018	<0.002	<0.002	<0.002	<0.002	
PE172208.062	MDPZ7457C DUP	12/11/2023	Hydrasleeve	28	0.03	0.06	0.8	35	350					<0.005	1.700	<0.005	0.055	<0.0005	<0.005	0.018	<0.005	<0.005	<0.005	<0.005	
19-04258	MDPZ7458A	15/03/2019	Airlift																						
19-19463	MDPZ7458A	13/11/2019	Hydrasleeve	68																					
20-08048	MDPZ7458A	2/05/2020	Hydrasleeve	68						11	2.9	<0.0002	0.9												
21-14674	MDPZ7458A	5/08/2021	Hydrasleeve	68																					
PE157146	MDPZ7458A	4/12/2021	Hydrasleeve	68	<0.02			22	560																
PE161850	MDPZ7458A	7/07/2022	Hydrasleeve	68		<0.2	2.3	23	580					<0.005	2.3	<0.005	0.017	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	32
PE164581	MDPZ7458A	23/10/2022	Hydrasleeve	68		<0.2	2.4	22	610					<0.005	2.2	<0.005	0.011	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	30
PE168204 R0	MDPZ7458A	4/05/2023	Hydrasleeve	68		0.07	2.3	20	650					<0.005	2.20	<0.005	0.020	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
PE172208.057	MDPZ7458A	12/11/2023	Hydrasleeve	68	<0.02	<0.05	2.3	21	600					<0.005	2.300	<0.005	0.031	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
19-04258	MDPZ7458B	16/03/2019	Airlift																						
19-19463	MDPZ7458B	13/11/2019	Hydrasleeve	50																					
20-08048	MDPZ7458B	2/05/2020	Hydrasleeve	50						0.21	0.4	<0.0002	0.04												
21-14674	MDPZ7458B	5/08/2021	Hydrasleeve	50																					
PE157146	MDPZ7458B	4/12/2021	Hydrasleeve	50	0.04			24	630																
PE161850	MDPZ7458B	7/07/2022	Hydrasleeve	50		<0.2	2.5	27	600					<0.005	2.7	<0.005	0.02	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	9
PE164581	MDPZ7458B	23/10/2022	Hydrasleeve	50		<0.2	2.3	26	650					<0.005	2.4	<0.005	0.016	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<5
PE168204 R0	MDPZ7458B	4/05/2023	Hydrasleeve	50		<0.05	2.5	23	690					<0.005	2.30	<0.005	0.021	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
PE172208.058	MDPZ7458B	12/11/2023	Hydrasleeve	50	0.05	<0.05	2.5	26	630					<0.005	2.500	<0.005	0.022	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
19-04258	MDPZ7458C	16/03/2019	Airlift																						
19-19463	MDPZ7458C	13/11/2019	Hydrasleeve	8																					
20-08048	MDPZ7458C	2/05/2020	Hydrasleeve	8						0.15	<0.1	<0.0002	<0.01												
21-14674	MDPZ7458C	5/08/2021	Hydrasleeve	8																					
PE157146	MDPZ7458C	5/12/2021	Hydrasleeve	8	<0.02			40	530																
PE164581	MDPZ7458C	23/10/2022	Hydrasleeve	8		<0.2	11	42	510					0.007	2.4	<0.005	0.021	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<5

Lab Report	Bore ID	Sample Date	Sample Type	Sample Depth	Ammonium, NH4	Nitrite-N	Fluoride by ISE	Silicon, Si-Dissolved	Sulfur, S	Iron - Total	Aluminium - Total	Mercury - Total	Manganese - Total	Arsenic, As-Dissolved	Boron, B-Dissolved	Beryllium, Be-Dissolved	Barium, Ba-Dissolved	Cadmium, Cd-Dissolved	Cobalt, Co-Dissolved	Chromium, Cr-Dissolved	Copper, Cu-Dissolved	Molybdenum, Mo-Dissolved	Nickel, Ni-Dissolved	Lead, Pb-Dissolved	Total Suspended Solids (TSS)
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
PE168204 R0	MDPZ7458C	4/05/2023	Hydrasleeve	8		<0.05	3.9	39	500					0.007	2.40	<0.005	0.027	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
PE172208.059	MDPZ7458C	12/11/2023	Hydrasleeve	8	0.05	<0.05	3.6	42	510					0.008	2.500	<0.005	0.029	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
19-04258	MDPZ7459	18/03/2019	Airlift																						
19-19463	MDPZ7459	12/11/2019	Hydrasleeve	20																					
20-08048	MDPZ7459	3/05/2020	Hydrasleeve	20						11	5	<0.0002	0.18												
21-05186	MDPZ7459	17/03/2021	Hydrasleeve	20																					
PE157146	MDPZ7459	6/12/2021	Hydrasleeve	20	0.04			35	3.7																
PE161850	MDPZ7459	6/07/2022	Hydrasleeve	20		<0.2	0.3	33	3.2					0.001	0.19	<0.001	0.13	<0.0001	<0.001	0.002	<0.001	0.002	<0.001	<0.001	78
PE164581	MDPZ7459	21/10/2022	Hydrasleeve	20		<0.2	0.5	40	3.2					0.001	0.23	<0.001	0.13	<0.0001	<0.001	0.002	<0.001	0.001	<0.001	<0.001	510
PE168204 R0	MDPZ7459	4/05/2023	Hydrasleeve	20		<0.05	0.5	39	4.3					0.001	0.28	<0.001	0.220	<0.0001	<0.001	0.002	<0.001	0.001	<0.001	<0.001	
PE172208.037	MDPZ7459	12/11/2023	Hydrasleeve	20	<0.02	<0.05	0.7	46	5.1					0.001	0.250	<0.001	0.260	<0.0001	<0.001	0.002	<0.001	0.002	<0.001	<0.001	
19-08491	MDPZ7460A	30/05/2019	Airlift																						
19-19463	MDPZ7460A	13/11/2019	Hydrasleeve	85																					
20-08048	MDPZ7460A	2/05/2020	Hydrasleeve	85						2.6	0.2	<0.0002	0.4												
21-05186	MDPZ7460A	17/03/2021	Hydrasleeve	85																					
PE157146	MDPZ7460A	7/12/2021	Hydrasleeve	85	0.09			13	230																
PE161850	MDPZ7460A	9/07/2022	Hydrasleeve	85		<0.2	1.1	12	240					<0.001	0.78	<0.001	0.011	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	78
PE164581	MDPZ7460A	26/10/2022	Hydrasleeve	85			1.1	13	240																50
PE168204 R0	MDPZ7460A	5/05/2023	Hydrasleeve	85		<0.05	1.0	14	220					<0.001	0.71	<0.001	0.035	<0.0001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	
PE172208.009	MDPZ7460A	12/11/2023	Hydrasleeve	85	0.05	<0.05	1.0	12	230					<0.001	0.790	<0.001	0.022	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	
19-08491	MDPZ7460B	29/05/2019	Airlift																						
19-19463	MDPZ7460B	13/11/2019	Hydrasleeve	49																					
20-08048	MDPZ7460B	2/05/2020	Hydrasleeve	49						0.43	0.1	<0.0002	<0.01												
21-05186	MDPZ7460B	17/03/2021	Hydrasleeve	49																					
PE157146	MDPZ7460B	7/12/2021	Hydrasleeve	49	0.02			28	170																
PE161850	MDPZ7460B	9/07/2022	Hydrasleeve	49		<0.2	0.8	26	180					<0.001	0.5	<0.001	0.008	<0.0001	<0.001	0.004	<0.001	<0.001	<0.001	<0.001	31
PE164581	MDPZ7460B	26/10/2022	Hydrasleeve	49			0.8	29	180																22
PE168204 R0	MDPZ7460B	5/05/2023	Hydrasleeve	49		<0.05	0.8	26	170					<0.001	0.63	<0.001	0.024	<0.0001	<0.001	0.004	<0.001	<0.001	<0.001	<0.001	
PE172208.010	MDPZ7460B	12/11/2023	Hydrasleeve	49	<0.02	<0.05	0.7	27	170					<0.001	0.430	<0.001	0.023	<0.0001	<0.001	0.005	<0.001	<0.001	<0.001	<0.001	
19-08491	MDPZ7460C	26/05/2019	Airlift																						
19-19463	MDPZ7460C	13/11/2019	Hydrasleeve	25																					
20-08048	MDPZ7460C	2/05/2020	Hydrasleeve	25						2.3	0.5	<0.0002	0.02												
21-05186	MDPZ7460C	17/03/2021	Hydrasleeve	25																					
PE157146	MDPZ7460C	7/12/2021	Hydrasleeve	25	<0.02			31	150																
PE161850	MDPZ7460C	9/07/2022	Hydrasleeve	25		<0.2	0.8	28	170					<0.001	0.68	<0.001	0.025	<0.0001	<0.001	0.005	<0.001	<0.001	<0.001	<0.001	39
PE164581	MDPZ7460C	26/10/2022	Hydrasleeve	25			0.8	32	170																33
PE168102 R0	MDPZ7460C	4/05/2023	Hydrasleeve	25		<0.05	0.4	29	180					<0.001	0.37	<0.001	0.045	<0.0001	<0.001	0.005	<0.001	<0.001	<0.001	<0.001	
PE172208.011	MDPZ7460C	12/11/2023	Hydrasleeve	25	0.02	<0.05	0.8	29	160					<0.001	0.470	<0.001	0.031	<0.0001	<0.001	0.005	<0.001	<0.001	<0.001	<0.001	
20-08574	MDPZ7461	10/05/2020	Hydrasleeve	20							<0.1		<0.01												
21-14674	MDPZ7461	5/08/2021	Hydrasleeve	20																					
PE157146	MDPZ7461	5/12/2021	Hydrasleeve	20	<0.02			32	250																
PE161850	MDPZ7461	7/07/2022	Hydrasleeve	20		<0.2	1.2	33	260					0.001	0.98	<0.001	0.002	<0.0001	<0.001	0.006	<0.001	<0.001	<0.001	<0.001	40
PE164581	MDPZ7461	23/10/2022	Hydrasleeve	20		<0.2	1.3	34	260					<0.001	0.97	<0.001	0.002	<0.0001	<0.001	0.004	<0.001	<0.001	<0.001	<0.001	100
PE168204 R0	MDPZ7461	4/05/2023	Hydrasleeve	20		<0.05	1.3	31	260					0.001	0.96	<0.001	0.023	<0.0001	<0.001	0.004	<0.001	<0.001	<0.001	<0.001	
PE172208.053	MDPZ7461	12/11/2023	Hydrasleeve	20	0.03	<0.05	0.9	34	260					<0.002	1.000	<0.002	0.026	<0.0002	<0.002	0.004	<0.002	<0.002	<0.002	<0.002	
19-04524	MDPZ7462A	22/03/2019	Airlift																						
19-19463	MDPZ7462A	12/11/2019	Hydrasleeve	115																					
20-08048	MDPZ7462A	3/05/2020	Hydrasleeve	115						2.9	0.4	<0.0002	6												
19-04524	MDPZ7462B	22/03/2019	Airlift																						
19-19463	MDPZ7462B	12/11/2019	Hydrasleeve	55																					
20-08048	MDPZ7462B	3/05/2020	Hydrasleeve	55						9.8	18	<0.0002	0.82												
19-04524	MDPZ7462C	22/03/2019	Airlift																						
19-19463	MDPZ7462C	12/11/2019	Hydrasleeve	30																					
20-08048	MDPZ7462C	3/05/2020	Hydrasleeve	30						1.1	0.3	<0.0002	0.02												
19-05368	MDPZ7463	1/04/2019	Airlift																						
19-19463	MDPZ7463 Lower	12/11/2019	Hydrasleeve	80																					
20-08048	MDPZ7463 Lower	4/05/2020	Hydrasleeve	80						4.1	1.2	<0.0002	0.05												
21-05186	MDPZ7463 Lower	17/03/2021	Hydrasleeve	80																					
PE157146	MDPZ7463 Lower	1/12/2021	Hydrasleeve	80	0.02			26	350																
PE161850	MDPZ7463 Lower	6/07/2022	Hydrasleeve	80		<0.2	1.3	23	470					<0.001	1.5	<0.001	0.035	<0.0001	<0.001	0.008	<0.001	0.003	0.003	<0.001	100
PE164581	MDPZ7463 Lower	21/10/2022	Hydrasleeve	80		N.A.	1.1	24	530					N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	190
PE172208.039	MDPZ7463 Lower	12/11/2023	Hydrasleeve	80	<0.02	<0.05	1.3	28	260					<0.001	1.200	<0.001	0.037	<0.0001	<0.001	0.011	<0.001	0.003	<0.001	<0.001	
19-19463	MDPZ7463 Upper	12/11/2019	Hydrasleeve	15																					
20-08048	MDPZ7463 Upper	4/05/2020	Hydrasleeve	15						1.5	0.5	<0.0002	0.02												
21-05186	MDPZ7463 Upper	17/03/2021	Hydrasleeve	15																					
PE157146	MDPZ7463 Upper	1/12/2021	Hydrasleeve	15	0.03			28	180																
PE161850	MDPZ7463 Upper	6/07/2022	Hydrasleeve	15		<0.2	0.9	27	190					<0.001	0.93	<0.001	0.026	<0.0001	<0.001	0.013	<0.001	0.003	<0.001	<0.001	5
PE164581	MDPZ7463 Upper	21/10/2022	Hydrasleeve	15		<0.2	0.9	32	180					0.001	1	<0.001	0.026	<0.0001	<0.001	0.015	<0.001	0.003	<0.001	<0.001	10
PE172208.038	MDPZ7463 Upper	12/11/2023	Hydrasleeve	15	<0.02	<0.05	1.0	30	190					<0.001	1.100	<0.001	0.042	<0.0001	<0.001	0.014	<0.001	0.004	<0.001	<0.001	
PE168102 R0	MDPZ7463D	3/05/2023	Hydrasleeve	80		<0.05	1.3	23	460					<0.001	1.50	<0.001	0.051	<0.0001	<0.001	0.009	<0.001	0.004	<0.002	<0.001	
PE168102 R0	MDPZ7463S	3/05/2023	Hydrasleeve	15		<0.05	1.0	28	180					<0.001	0.98	<0.001	0.045	<0.0001	<0.001	0.013	<0.001	0.004	<0.001	<0.001	
19-05776	MDPZ7464	5/04/2019	Airlift																						
19-19463	MDPZ7464 Lower	12/11/2019	Hydrasleeve	85																					
20-08048	MDPZ7464 Lower	3/05/2020	Hydrasleeve	85						9.7	4.1	<0.0002	0.5												
21-05186	MDPZ7464 Lower	16/03/2021	Hydrasleeve	85																					
PE157146	MDPZ7464 Lower	6/12/2021	Hydrasleeve	85	<0.02			14	640																
PE161850	MDPZ7464 Lower	6/07/2022	Hydrasleeve	85		<0.2	2.2	9.7	900					<0.005	4.1	<0.005	0.006	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	240
PE164581	MDPZ7464 Lower	21/10/2022	Hydrasleeve	80		<0.2	1.8	12	900					<0.005	3.7	<0.005	0.016	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	1,400
PE172208.041	MDPZ7464 Lower	12/11/2023	Hydrasleeve	80	<0.02	<0.05	2.4	23	350					<0.002	1.700	<0.002	0.039	<0.0002	<0.002	0.004	<0.002	<0.002	0.002	0.002	
19-19463	MDPZ7464 Upper	12/11/2019	Hydrasleeve	15																					
20-08048	MDPZ7464 Upper	3/05/2020	Hydrasleeve	15						26	11	<0.0002	0.74												
21-05186	MDPZ7464 Upper	16/03/2021	Hydrasleeve	15																					
PE157146	MDPZ7464 Upper	6/12/2021	Hydrasleeve	15	<0.02			26	69																
PE161850	MDPZ7464 Upper	6/07/2022	Hydrasleeve	15		<0.2	1.1	25	79					<0.001	0.53	<0.001	0.059	<0.0001	<0.001	0.004	<0.001	0.002	<0.001	<0.001	50
PE164581	MDPZ7464 Upper	21/10/2022	Hydrasleeve	15		<0.2	1.3	30	53					<0.001	0.55	<0.001	0.04	<0.0001	<0.001	0.004	<0.001	0.002	<0.001	<0.001	57
PE172208.040	MDPZ7464 Upper	12/11/2023	Hydrasleeve	15	<0.02	<0.05	1.3	29	44					<0.001	0.400	<0.001	0.072	<0.0001	<0.001	0.004	<0.001	0.002	<0.001	<0.001	
PE168102 R0	MDPZ7464D	3/05/2023	Hydrasleeve	80		<0.05	2.4	8.7	890					<0.005	3.80	<0.005	0.009	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
PE168102 R0	MDPZ7464S	3/05/2023	Hydrasleeve	15		<0.05	1.3	27	41					<0.001	0.30	<0.001	0.085	<0.0001	<0.001	0.004	<0.001	0.002	<0.001	<0.001	
19-05776	MDPZ7465	9/04/2019	Airlift																						
20-08574	MDPZ7465	10/05/2020	Hydrasleeve	90							<0.1		0.9												
PE161850	MDPZ7465	9/07/2022	Hydrasleeve	90		<0.2	0.2	22	0.2					0.011	1.4	<0.001	1	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	72
PE164581	MDPZ7465	26/10/2022	Hydrasleeve	90			0.2	24	0.8																150
PE168204 R0	MDPZ7465	5/05/2023	Hydrasleeve	90	<0.02	<0.05	0.2	22	0.3					0.020	1.50	<0.001	0.940	<0.0001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	
PE172208.017	MDPZ7465	13/11/2023	Hydrasleeve	90	0.27	<0.05	0.2	23	0.2					0.016	1.600	<0.001	0.950	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	
PE172208.018	MDPZ7465_DUP	13/11/2023	Hydrasleeve	90	0.28	<0.05	0.2	24	0.1					0.021	1.600	<0.001	1.000	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	
19-06249	MDPZ7466	26/04/2019	Airlift																						
19-19847	MDPZ7466 Lower	17/11/2019	Hydrasleeve	60																					
20-08048	MDPZ7466 Lower	4/05/2020	Hydrasleeve	60						9.1	5.3	<0.0002	2.8												

Lab Report	Bore ID	Sample Date	Sample Type	Sample Depth	Ammonium, NH4	Nitrite-N	Fluoride by ISE	Silicon, Si-Dissolved	Sulfur, S	Iron - Total	Aluminium - Total	Mercury - Total	Manganese - Total	Arsenic, As-Dissolved	Boron, B-Dissolved	Beryllium, Be-Dissolved	Barium, Ba-Dissolved	Cadmium, Cd-Dissolved	Cobalt, Co-Dissolved	Chromium, Cr-Dissolved	Copper, Cu-Dissolved	Molybdenum, Mo-Dissolved	Nickel, Ni-Dissolved	Lead, Pb-Dissolved	Total Suspended Solids (TSS)
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
21-05186	MDPZ7466 Lower	16/03/2021	Hydrasleeve	60																					
PE157146	MDPZ7466 Lower	8/12/2021	Hydrasleeve	60	0.03			33	160																
PE161850	MDPZ7466 Lower	9/07/2022	Hydrasleeve	60		<0.2	0.9	34	200					<0.001	0.68	0.003	0.018	0.0021	0.059	<0.001	0.013	<0.001	0.12	0.003	58
PE164581	MDPZ7466 Lower	26/10/2022	Hydrasleeve	60		N.A.	1	28	4.2					N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	120
19-19847	MDPZ7466 Upper	17/11/2019	Hydrasleeve	40																					
20-08048	MDPZ7466 Upper	4/05/2020	Hydrasleeve	40						12	3.6	<0.0002	0.46												
21-05186	MDPZ7466 Upper	16/03/2021	Hydrasleeve	40																					
PE157146	MDPZ7466 Upper	8/12/2021	Hydrasleeve	40	<0.02			25	4.1																
PE161850	MDPZ7466 Upper	9/07/2022	Hydrasleeve	40		<0.2	0.3	25	4.1					<0.001	0.2	<0.001	0.013	<0.0001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	67
PE164581	MDPZ7466 Upper	26/10/2022	Hydrasleeve	40		N.A.	0.2	38	200					N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	140
PE168204 R0	MDPZ7466D	5/05/2023	Hydrasleeve	60		<0.05	0.8	28	98					<0.001	0.38	0.001	0.025	0.0010	0.026	<0.001	0.006	<0.001	0.057	0.001	
PE172208.020	MDPZ7466D	14/11/2023	Hydrasleeve	60	<0.02	<0.05	0.8	37	220					<0.001	0.750	<0.003	0.038	0.002	0.055	<0.001	0.013	<0.001	0.120	0.003	
PE168204 R0	MDPZ7466S	5/05/2023	Hydrasleeve	40		<0.05	0.3	23	3.6					<0.001	0.20	<0.001	0.065	<0.0001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	
PE172208.019	MDPZ7466S	14/11/2023	Hydrasleeve	40	<0.02	<0.05	0.3	26	4.2					<0.001	0.150	<0.001	0.056	<0.0001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	
19-06249	MDPZ7467	26/04/2019	Airlift																						
19-19847	MDPZ7467 Lower	17/11/2019	Hydrasleeve	62																					
20-08048	MDPZ7467 Lower	4/05/2020	Hydrasleeve	62						11	1.7	<0.0002	1.3												
21-05186	MDPZ7467 Lower	16/03/2021	Hydrasleeve	62																					
PE157146	MDPZ7467 Lower	8/12/2021	Hydrasleeve	62	0.15			11	150																
PE161850	MDPZ7467 Lower	10/07/2022	Hydrasleeve	62		<0.2	1.1	12	160					0.015	0.65	<0.001	0.016	<0.0001	0.002	<0.001	<0.001	<0.001	0.006	<0.001	31
PE164581	MDPZ7467 Lower	26/10/2022	Hydrasleeve	62		N.A.	1.2	13	150					N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	75
19-19847	MDPZ7467 Upper	17/11/2019	Hydrasleeve	50																					
20-08048	MDPZ7467 Upper	4/05/2020	Hydrasleeve	50						21	2.9	<0.0002	1.4												
21-05186	MDPZ7467 Upper	16/03/2021	Hydrasleeve	50																					
PE157146	MDPZ7467 Upper	8/12/2021	Hydrasleeve	50	0.54			12	110																
PE161850	MDPZ7467 Upper	10/07/2022	Hydrasleeve	50		<0.2	1.2	14	120					0.019	0.54	<0.001	0.011	<0.0001	0.005	<0.001	<0.001	<0.001	0.012	<0.001	66
PE164581	MDPZ7467 Upper	26/10/2022	Hydrasleeve	50		N.A.	1.3	15	110					N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	44
PE168204 R0	MDPZ7467D	5/05/2023	Hydrasleeve	62		<0.05	1.2	11	150					0.022	0.63	<0.001	0.028	<0.0001	0.002	<0.001	<0.001	<0.001	0.006	<0.001	
PE172208.064	MDPZ7467D	14/11/2023	Hydrasleeve	62	0.11	<0.05	1.2	12	160					0.019	0.720	<0.001	0.032	<0.0001	0.001	<0.001	<0.001	<0.001	0.004	<0.001	
PE168204 R0	MDPZ7467S	5/05/2023	Hydrasleeve	50		<0.05	1.2	13	110					0.022	0.48	<0.001	0.029	0.0001	0.005	<0.001	<0.001	<0.001	0.011	<0.001	
PE172208.063	MDPZ7467S	14/11/2023	Hydrasleeve	50	0.11	<0.05	1.1	14	110					0.025	0.610	<0.001	0.055	<0.0001	0.004	<0.001	<0.001	<0.001	0.010	<0.001	
19-06249	MDPZ7468A	26/04/2019	Airlift																						
19-19463	MDPZ7468A	12/11/2019	Hydrasleeve	85																					
20-08048	MDPZ7468A	3/05/2020	Hydrasleeve	85						1.6	0.3	<0.0002	1.8												
21-14674	MDPZ7468A	5/08/2021	Hydrasleeve	85																					
PE157146	MDPZ7468A	1/12/2021	Hydrasleeve	85	<0.02			9.4	1100																
PE161850	MDPZ7468A	6/07/2022	Hydrasleeve	62		<0.2	2.8	6.6	1200					<0.005	4.2	<0.005	0.024	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	31
PE164581	MDPZ7468A	21/10/2022	Hydrasleeve	85		<0.2	2.7	7.9	1100					<0.005	4.4	<0.005	0.024	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	17
PE168102 R0	MDPZ7468A	3/05/2023	Hydrasleeve	85		<0.05	2.6	8.7	1200					0.01	4.00	<0.010	0.026	<0.0001	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	
PE172208.065	MDPZ7468A	12/11/2023	Hydrasleeve	85	0.03	<0.05	2.7	19	1000					<0.005	4.000	<0.005	0.029	<0.0005	<0.005	<0.005	<0.005	0.007	<0.005	<0.005	
19-06249	MDPZ7468B	26/04/2019	Airlift																						
19-19463	MDPZ7468B	12/11/2019	Hydrasleeve	60																					
20-08048	MDPZ7468B	3/05/2020	Hydrasleeve	60						0.94	0.6	<0.0002	<0.01												
21-14674	MDPZ7468B	5/08/2021	Hydrasleeve	60																					
PE157146	MDPZ7468B	1/12/2021	Hydrasleeve	60	0.02			23	790																
PE161850	MDPZ7468B	6/07/2022	Hydrasleeve	50		<0.2	2	23	770					<0.005	3.4	<0.005	0.017	<0.0005	<0.005	0.005	<0.005	0.009	0.007	<0.005	120
PE164581	MDPZ7468B	21/10/2022	Hydrasleeve	60		<0.2	2.2	23	810					<0.001	3.1	<0.001	0.018	<0.0001	<0.001	0.006	<0.001	0.009	0.006	<0.001	18
PE168102 R0	MDPZ7468B	3/05/2023	Hydrasleeve	60		<0.05	2.2	23	860					<0.005	3.30	<0.005	0.025	<0.0005	<0.005	0.006	<0.005	0.008	<0.007	<0.005	
PE172208.066	MDPZ7468B	12/11/2023	Hydrasleeve	60	<0.02	<0.05	2.2	23	720					<0.005	3.500	<0.005	0.021	<0.0005	<0.005	0.005	<0.005	0.008	0.005	0.005	
19-06249	MDPZ7468C	26/04/2019	Airlift																						
19-19463	MDPZ7468C	13/11/2019	Hydrasleeve	30																					
20-08048	MDPZ7468C	3/05/2020	Hydrasleeve	30						25	10	<0.0002	0.33												
21-14674	MDPZ7468C	5/08/2021	Hydrasleeve	30																					
PE157146	MDPZ7468C	1/12/2021	Hydrasleeve	30	<0.02			23	510																
PE161850	MDPZ7468C	6/07/2022	Hydrasleeve	85		<0.2	1.1	23	550					<0.005	2.5	<0.005	0.027	<0.0005	<0.005	0.016	<0.005	0.006	<0.005	<0.005	420
PE164581	MDPZ7468C	21/10/2022	Hydrasleeve	30		<0.2	1	23	540					<0.002	2.5	<0.002	0.024	<0.0002	<0.002	0.015	<0.002	0.006	<0.002	<0.002	91
PE168102 R0	MDPZ7468C	3/05/2023	Hydrasleeve	30		<0.05	1.1	23	560					<0.005	2.50	<0.005	0.032	<0.0005	<0.005	0.015	<0.005	0.006	<0.005	<0.005	
PE172208.067	MDPZ7468C	12/11/2023	Hydrasleeve	30	<0.02	<0.05	1.1	24	540					<0.005	2.700	<0.005	0.033	<0.0005	<0.005	0.014	<0.005	0.006	<0.005	<0.005	
19-06460	MDPZ7469A	29/04/2019	Airlift																						
19-19463	MDPZ7469A	13/11/2019	Hydrasleeve	100																					
20-08048	MDPZ7469A	2/05/2020	Hydrasleeve	100						44	19	<0.0002	5.9												
21-05186	MDPZ7469A	16/03/2021	Hydrasleeve	100																					
PE161850	MDPZ7469A	8/07/2022	Hydrasleeve	60		<0.2	2.1	6.8	780					<0.005	2.1	<0.005	0.016	<0.0005	0.006	<0.005	<0.005	<0.005	0.017	<0.005	140
PE164581	MDPZ7469A	26/10/2022	Hydrasleeve	100		<0.2	1.9	10	790					<0.005	2.6	<0.005	0.037	<0.0005	<0.005	<0.005	<0.005	<0.005	0.011	<0.005	310
PE168204 R0	MDPZ7469A	5/05/2023	Hydrasleeve	100		<0.05	2.2	11	840					<0.005	2.60	<0.005	0.048	<0.0005	<0.005	<0.005	<0.005	<0.005	0.005	<0.005	
PE172208.002	MDPZ7469A	12/11/2023	Hydrasleeve	100	0.05	<0.05	2.0	7.1	830					<0.005	2.700	<0.005	0.021	<0.0005	<0.005	<0.005	<0.005	<0.005	0.015	<0.005	
19-06460	MDPZ7469B	29/04/2019	Airlift																						
19-19463	MDPZ7469B	13/11/2019	Hydrasleeve	75																					
20-08048	MDPZ7469B	2/05/2020	Hydrasleeve	75						5.9	1.5	<0.0002	0.12												
21-05186	MDPZ7469B	16/03/2021	Hydrasleeve	75																					
PE161850	MDPZ7469B	8/07/2022	Hydrasleeve	30		<0.2	0.7	27	130					<0.001	0.44	<0.001	0.009	<0.0001	<0.001	0.004	<0.001	<0.001	0.001	<0.001	92
PE164581	MDPZ7469B	26/10/2022	Hydrasleeve	75		<0.2	0.7	29	130					<0.001	0.52	<0.001	0.006	<0.0001	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	31
PE168204 R0	MDPZ7469B	5/05/2023	Hydrasleeve	75		<0.05	0.7	26	130					<0.001	0.50	<0.001	0.029	<0.0001	<0.001	0.004	<0.001	<0.001	<0.001	<0.001	
PE172208.003	MDPZ7469B	12/11/2023	Hydrasleeve	75	0.02	<0.05	0.9	28	130					<0.001	0.440	<0.001	0.024	<0.0001	<0.001	0.004	<0.001	<0.001	<0.001	<0.001	
19-06460	MDPZ7469C	29/04/2019	Airlift																						
19-19463	MDPZ7469C	13/11/2019	Hydrasleeve	35																					
20-08048	MDPZ7469C	2/05/2020	Hydrasleeve	35						2.4	0.6	<0.0002	0.04												
21-05186	MDPZ7469C	16/03/2021	Hydrasleeve	35																					
PE161850	MDPZ7469C	8/07/2022	Hydrasleeve	100		<0.2	0.8	28	110					<0.001	0.44	<0.001	0.04	<0.0001	<0.001	0.006	<0.001	<0.001	<0.001	<0.001	9
PE164581	MDPZ7469C	26/10/2022	Hydrasleeve	35		<0.2	0.8	31	110					<0.001	0.51	<0.001	0.039	<0.0001	<0.001	0.007	<0.001	<0.001	<0.001	<0.001	8
PE168204 R0	MDPZ7469C	5/05/2023	Hydrasleeve	35		<0.05	0.8	26	110					<0.001	0.49	<0.001	0.056	<0.0001	<0.001	0.007	<0.001	<0.001	<0.001	<0.001	
PE172208.004	MDPZ7469C	12/11/2023	Hydrasleeve	35	<0.02	<0.05	0.8	27	110					<0.001	0.420	<0.001	0.042	<0.0001	<0.001	0.008	<0.001	<0.001	<0.001	<0.001	
19-12584	MDPZ7470A	25/07/2019	Airlift																						
19-19463	MDPZ7470A	13/11/2019	Hydrasleeve	90																					
20-08048	MDPZ7470A	2/05/2020	Hydrasleeve	90						3.1	0.9	<0.0002	1.6												
21-14674	MDPZ7470A	5/08/2021	Hydrasleeve	90																					
PE157146	MDPZ7470A	1/12/2021	Hydrasleeve	90	0.22			25	290																
PE161850	MDPZ7470A	8/07/2022	Hydrasleeve	75		<0.2	1.4	24	320					<0.002	1.1	<0.002	0.019	<0.0002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	12
PE164581	MDPZ7470A	26/10/2022	Hydrasleeve	90			1.4	24	340																16
PE168204 R0	MDPZ7470A	5/05/2023	Hydrasleeve	90		<0.05	1.5	22	350					<0.002	1.10	<0.002	0.024	<0.0002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	
PE172208.005	MDPZ7470A	12/11/2023	Hydrasleeve	90	<0.02	<0.05	1.4	25	320					<0.002	1.100	<0.002	0.013	<0.0002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	
19-12584	MDPZ7470B	25/07/2019	Airlift																						
19-19463	MDPZ7470B	13/11/2019	Hydrasleeve	45																					
20-08048	MDPZ7470B	2/05/2020	Hydrasleeve	45						1.7	0.6	<0.0002	0.02												
21-14674	MDPZ7470B	5/08/2021	Hydrasleeve	45																					
PE157146	MDPZ7470B	1/12/2021	Hydrasleeve	45	0.33			35	230																
PE161850	MDPZ7470B	8/07/2022	Hydrasleeve	35		<0.2	2.2	35	240					0.002	1.1	<0.001	0.032	<0.0001	<0.001	0.009	<0.001	0.002	<0.001	<0.001	11
PE164581	MDPZ7470B	26/10/2022	Hydrasleeve	45			2.2	39	230																18

Lab Report	Bore ID	Sample Date	Sample Type	Sample Depth	Ammonium, NH4	Nitrite-N	Fluoride by ISE	Silicon, Si-Dissolved	Sulfur, S	Iron - Total	Aluminium - Total	Mercury - Total	Manganese - Total	Arsenic, As-Dissolved	Boron, B-Dissolved	Beryllium, Be-Dissolved	Barium, Ba-Dissolved	Cadmium, Cd-Dissolved	Cobalt, Co-Dissolved	Chromium, Cr-Dissolved	Copper, Cu-Dissolved	Molybdenum, Mo-Dissolved	Nickel, Ni-Dissolved	Lead, Pb-Dissolved	Total Suspended Solids (TSS)
					mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
PE168204 R0	MDPZ7470B	5/05/2023	Hydrasleeve	45		<0.05	2.3	34	240					0.002	1.10	<0.001	0.040	<0.0001	<0.001	0.008	<0.001	0.002	<0.001	<0.001	
PE172208.006	MDPZ7470B	12/11/2023	Hydrasleeve	45	<0.02	<0.05	2.2	36	230					0.002	1.200	<0.001	0.032	<0.0001	<0.001	0.009	<0.001	0.002	<0.001	<0.001	
19-12584	MDPZ7470C	24/07/2019	Airlift																						
19-19463	MDPZ7470C	13/11/2019	Hydrasleeve	20																					
20-08048	MDPZ7470C	2/05/2020	Hydrasleeve	20						6	1.9	<0.0002	0.12												
21-14674	MDPZ7470C	5/08/2021	Hydrasleeve	20																					
PE157146	MDPZ7470C	1/12/2021	Hydrasleeve	20	9.2			35	200																
PE161850	MDPZ7470C	8/07/2022	Hydrasleeve	90		<0.2	2.2	35	240					0.003	1.3	<0.001	0.067	<0.0001	<0.001	0.009	<0.001	0.003	<0.001	<0.001	9
PE164581	MDPZ7470C	26/10/2022	Hydrasleeve	20			2.1	38	250																30
PE168204 R0	MDPZ7470C	5/05/2023	Hydrasleeve	20	<0.02	<0.05	2.2	33	230					0.003	1.30	<0.001	0.084	<0.0001	<0.001	0.007	<0.001	0.002	<0.001	<0.001	
PE172208.007	MDPZ7470C	12/11/2023	Hydrasleeve	20	0.02	<0.05	2.2	37	230					0.003	1.300	<0.001	0.059	<0.0001	<0.001	0.010	<0.001	0.002	<0.001	<0.001	
PE172208.008	MDPZ7470C_DUP	12/11/2023	Hydrasleeve	20	<0.02	<0.05	2.2	37	210					0.003	1.400	<0.001	0.063	<0.0001	<0.001	0.007	<0.001	0.002	<0.001	<0.001	
19-12584	MDPZ7471A	31/07/2019	Airlift																						
19-19463	MDPZ7471A	13/11/2019	Hydrasleeve	72																					
20-08048	MDPZ7471A	3/05/2020	Hydrasleeve	72						0.8	0.3	<0.0002	0.01												
21-14674	MDPZ7471A	5/08/2021	Hydrasleeve	72																					
PE157146	MDPZ7471A	6/12/2021	Hydrasleeve	72	<0.02			28	410																
PE161850	MDPZ7471A	6/07/2022	Hydrasleeve	45		<0.2	1.6	29	420					<0.002	1.7	<0.002	0.026	<0.0002	<0.002	0.004	<0.002	<0.002	<0.002	<0.002	43
PE164581	MDPZ7471A	19/10/2022	Hydrasleeve	72		<0.2	1.4	32	390					<0.002	1.8	<0.002	0.023	<0.0002	<0.002	0.004	<0.002	<0.002	<0.002	<0.002	27
PE168102 R0	MDPZ7471A	3/05/2023	Hydrasleeve	72		<0.05	1.5	29	420					<0.002	1.60	<0.002	0.035	<0.0002	<0.002	0.003	<0.002	<0.002	<0.002	<0.002	
PE172208.068	MDPZ7471A	12/11/2023	Hydrasleeve	72	<0.02	0.05	1.6	30	410					<0.005	1.800	<0.005	0.028	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
19-12584	MDPZ7471B	31/07/2019	Airlift																						
19-19463	MDPZ7471B	12/11/2019	Hydrasleeve	55																					
20-08048	MDPZ7471B	3/05/2020	Hydrasleeve	55						0.53	0.2	<0.0002	<0.01												
21-14674	MDPZ7471B	5/08/2021	Hydrasleeve	55																					
PE157146	MDPZ7471B	6/12/2021	Hydrasleeve	55	<0.02			27	430																
19-12584	MDPZ7471C	31/07/2019	Airlift																						
19-19463	MDPZ7471C	12/11/2019	Hydrasleeve	15																					
20-08048	MDPZ7471C	3/05/2020	Hydrasleeve	15						1.4	0.5	<0.0002	0.01												
21-14674	MDPZ7471C	5/08/2021	Hydrasleeve	15																					
PE157146	MDPZ7471C	6/12/2021	Hydrasleeve	15	<0.02			37	310																
PE161850	MDPZ7471C	6/07/2022	Hydrasleeve	20		<0.2	1.5	36	350					<0.002	2.4	<0.002	0.036	<0.0002	<0.002	0.009	<0.002	0.005	<0.002	<0.002	5
PE164581	MDPZ7471C	19/10/2022	Hydrasleeve	15		<0.2	1.5	39	370					<0.002	2.4	<0.002	0.035	<0.0002	<0.002	0.009	<0.002	0.005	<0.002	<0.002	11
PE168102 R0	MDPZ7471C	3/05/2023	Hydrasleeve	15		<0.05	1.6	37	290					0.002	2.40	<0.001	0.048	<0.0001	<0.001	0.007	<0.001	0.007	<0.001	<0.001	
PE172208.070	MDPZ7471C	12/11/2023	Hydrasleeve	15	<0.02	<0.05	1.6	39	310					<0.002	2.600	<0.002	0.040	<0.0002	<0.002	0.008	<0.002	0.007	<0.002	<0.002	
PE153340	MDPZ9201	9/07/2021	Airlift			<0.2	1.0	13	120					<0.001	0.47	<0.001	0.035	<0.0001	0.001	<0.001	<0.001	<0.001	0.001	<0.001	1900
PE153340	MDPZ9202	13/07/2021	Airlift			<0.2	0.8	18	110					<0.001	0.5	<0.001	0.061	<0.0001	0.002	0.002	<0.001	<0.001	0.004	<0.001	1200
PE153749	MDPZ9203	31/07/2021	Airlift			<0.2	0.5	25	98					<0.001	0.29	<0.001	0.07	<0.0001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	3600
PE153634	MDPZ9204	20/07/2021	Airlift			<0.2	0.6	25	120					<0.001	0.43	<0.001	0.017	<0.0001	<0.001	0.002	<0.001	<0.001	0.001	<0.001	140
PE153749	MDPZ9205	24/07/2021	Airlift			<0.2	0.6	22	92					<0.001	0.37	<0.001	0.031	<0.0001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	45
PE157321	MDPZ9205	15/12/2021	Hydrasleeve	35	<0.02			22	93																
PE161850	MDPZ9205	9/07/2022	Hydrasleeve	35		<0.2	0.6	24	98					<0.001	0.45	<0.001	0.034	<0.0001	<0.001	0.003	<0.001	<0.001	0.002	<0.001	410
PE164581	MDPZ9205	26/10/2022	Hydrasleeve	35			0.6	24	100																120
PE168204 R0	MDPZ9205	5/05/2023	Hydrasleeve	35		<0.05	0.6	25	83					<0.001	0.41	<0.001	0.056	<0.0001	<0.001	0.002	<0.001	<0.001	0.001	<0.001	
PE172208.016	MDPZ9205	13/11/2023	Hydrasleeve	35	<0.02	<0.05	0.6	23	100					<0.001	0.310	<0.001	0.040	<0.0001	<0.001	0.002	<0.001	<0.001	0.002	<0.001	
PE153749	MDPZ9206	28/07/2021	Airlift			<0.2	1.0	7.6	190					0.004	0.52	<0.001	0.013	0.0002	0.014	<0.001	<0.001	<0.001	0.04	<0.001	55
PE154009	MDPZ9207	3/08/2021	Airlift			<0.2	0.8	18	70					0.002	0.33	<0.001	0.006	0.0002	0.001	<0.001	<0.001	<0.001	0.007	<0.001	14
PE154009	MDPZ9208	7/08/2021	Airlift			<0.2	0.7	24	83					<0.001	0.41	<0.001	0.02	<0.0001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<5
PE154009	MDPZ9209	11/08/2021	Airlift			<0.2	0.2	26	20					<0.001	0.2	<0.001	0.06	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	64
PE154235	MDPZ9210	15/08/2021	Airlift			<0.2	1.0	15	200					<0.001	0.72	<0.001	0.002	0.002	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	15
PE155073	MDPZ9211	17/09/2021	Airlift			<0.2	2.1	16	720					<0.005	2.7	<0.005	<0.005	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	9
PE157321	MDPZ9211	16/12/2021	Hydrasleeve	48	<0.02			24	530																
PE161850	MDPZ9211	7/07/2022	Hydrasleeve	48		<0.2	2.7	25	470					<0.002	1.8	<0.002	0.005	<0.0002	<0.002	0.005	<0.002	0.002	<0.002	<0.002	15
PE164581	MDPZ9211	23/10/2022	Hydrasleeve	48		<0.2	2.4	23	530					<0.005	1.8	<0.005	0.009	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	210
PE168204 R0	MDPZ9211	4/05/2023	Hydrasleeve	48		<0.05	2.2	24	530					<0.005	1.60	<0.005	0.017	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
PE172208.056	MDPZ9211	12/11/2023	Hydrasleeve	48	<0.02	<0.05	2.2	23	540					<0.005	2.000	<0.005	0.018	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
PE155073	MDPZ9212	24/09/2021	Airlift			<0.2	2.9	20	850					<0.005	3.2	<0.005	<0.005	<0.0005	<0.005	<0.005	<0.005	0.005	<0.005	<0.005	12
PE157321	MDPZ9212D	16/12/2021	Hydrasleeve	105	<0.02			20	840																
PE161850	MDPZ9212D	7/07/2022	Hydrasleeve	105		<0.2	3.3	21	820					<0.005	3.3	<0.005	0.015	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	56
PE164581	MDPZ9212D	23/10/2022	Hydrasleeve	105		<0.2	3.2	19	850					<0.005	3	<0.005	0.013	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	49
PE168204 R0	MDPZ9212D	4/05/2023	Hydrasleeve	105		0.12	3.4	17	800					<0.005	2.90	<0.005	0.019	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
PE172208.055	MDPZ9212D	12/11/2023	Hydrasleeve	105	<0.02	0.10	3.4	19	780					<0.005	3.200	<0.005	0.029	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
PE157321	MDPZ9212S	16/12/2021	Hydrasleeve	20	<0.02			37	690																
PE161850	MDPZ9212S	7/07/2022	Hydrasleeve	20		<0.2	3.1	42	650					0.009	3.3	<0.005	0.03	<0.0005	<0.005	<0.005	<0.005	0.006	<0.005	<0.005	29
PE164581	MDPZ9212S	23/10/2022	Hydrasleeve	20		<0.2	3.5	40	670					0.007	2.9	<0.005	0.024	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<5
PE168204 R0	MDPZ9212S	4/05/2023	Hydrasleeve	20		<0.05	3.4	38	730					0.007	3.10	<0.005	0.031	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
PE172208.054	MDPZ9212S	12/11/2023	Hydrasleeve	20	0.33	<0.05	3.2	38	690					0.005	3.100	<0.005	0.038	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
PE155297	MDPZ9213	1/10/2021	Airlift			<0.2	0.9	29	130					<0.001	0.46	<0.001	0.012	<0.0001	<0.001	0.005	<0.001	<0.001	<0.001	<0.001	210
PE157321	MDPZ9213	13/12/2021	Hydrasleeve	40	<0.02			28	85																
PE161850	MDPZ9213	6/07/2022	Hydrasleeve	40		<0.2	0.9	27	88					<0.001	0.39	<0.001	0.009	<0.0001	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	19
PE164581	MDPZ9213	19/10/2022	Hydrasleeve	40		<0.2	1	31	95					<0.001	0.46	<0.001	0.009	<0.0001	<0.001	0.004	<0.001	<0.001	<0.001	<0.001	75
PE168102 R0	MDPZ9213	3/05/2023	Hydrasleeve	40		<0.05	1.0	28	83					<0.001	0.26	<0.001	0.039	<0.0001	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	
PE172208.071	MDPZ9213	13/11/2023	Hydrasleeve	40	<0.02	<0.05	0.9	30	91					<0.001	0.430	<0.001	0.030	<0.0001	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	
PE155569	MDPZ9214	10/10/2021	Airlift			<0.2	1.2	35	310					0.001	1.2	<0.001	0.012	<0.0001	<0.001	0.005	<0.001	0.001	<0.001	<0.001	23
PE157321	MDPZ9214	15/12/2021	Hydrasleeve	40	<0.02			34	200																
PE161850	MDPZ9214	6/07/2022	Hydrasleeve	40		<0.2	1.4	33	210					0.002	1.1	<0.001	0.012	<0.0001	<0.001	0.005	<0.001	<0.001	<0.001	<0.001	33
PE164581	MDPZ9214	19/10/2022	Hydrasleeve	40		<0.2	1.3	37	200					0.001	1.2	<0.001	0.011	<0.0001	<0.001	0.006	<0.001	<0.001	<0.001	<0.001	16
PE168102 R0	MDPZ9214	3/05/2023	Hydrasleeve	40		<0.05	1.3	34	210					0.002	1.10	<0.001	0.034	<0.0001	<0.001	0.005	<0.001	<0.001	<0.001	<0.001	
PE172208.072	MDPZ9214	13/11/2023	Hydrasleeve	40	<0.02	<0.05	1.7	40	210					0.003	1.500	<0.001	0.037	<0.0001	<0.001	0.004	<0.001	0.004	<0.001	<0.001	
PE155734	MDPZ9215D	8/10/2021	Airlift			<0.2	2.3	12	1100					<0.005	4.5	<0.005	<0.005	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	66
PE157321	MDPZ9215D	15/12/2021	Hydrasleeve	80	<0.02			22	510																
PE161850	MDPZ9215D	6/07/2022	Hydrasleeve	80		<0.2	1.5	25	380					<0.002	1.5	<0.002	0.016	<0.0002	<0.002	0.005	<0.002	<0.002	<0.002	<0.002	560
PE164581	MDPZ9215D	19/10/2022	Hydrasleeve	80		<0.2	1.3	27	320					<0.001	1.4	<0.001	0.013	<0.0001	<0.001	0.005	<0.001	0.001	<0.001	<0.001	25
PE168102 R0	MDPZ9215D	3/05/2023	Hydrasleeve	80		<0.05	1.4	25	330					<0.001	1.30	<0.001	0.026	<0.0001	<0.001	0.004	<0.001	0.001	<0.001	<0.001	
PE172208.073	MDPZ9215D	12/11/2023	Hydrasleeve	80	<0.02	<0.05	1.2	26	430					<0.005	1.800	<0.005	0.067	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
PE155887	MDPZ9215S	27/10/2021	Airlift			<0.2	0.9		190					0.001	0.84	<0.001	0.046	<0.0001	<0.001	0.008	<0.001	0.001	<0.001	<0.001	57
PE157321	MDPZ9215S	15/12/2021	Hydrasleeve	20	<0.02			23	230																
PE161850	MDPZ9215S	6/07/2022	Hydrasleeve	20		<0.2	0.9	24	260					<0.001	1	<0.001	0.032	<0.0001	<0.001	0.009	<0.001	0.001	<0.001	<0.001	74
PE164581	MDPZ9215S	19/10/2022	Hydrasleeve	20		<0.2	0.9	26	250					<0.001	1.1	<0.001	0.028	<0.0001	<0.001	0.008	<0.001	<0.001	0.001	<0.001	11
PE168102 R0	MDPZ9215S	3/05/2023	Hydrasleeve	20	<0.02	<0.05	0.9	24	260					<0.001	1.10	<0.001	0.046	<0.0001	<0.001	0.007	<0.001	0.001	<0.001	<0.001	
PE172208.042	MDPZ9215S	12/11/2023	Hydrasleeve	20	<0.02	<0.05	1.1	34	160					0.004	0.970	<0.001	0.120	<0.0001	<0.001	0.004	<0.001	0.002	<0.001	<0.001	
PE155887	MDPZ9216	24/10/2021	Airlift			<0.2	2.6		1200					<0.005	4.3	<0.005	<0.005	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	6
PE157321	MDPZ9216	15/12/2021	Hydrasleeve	90	0.1			11	1100																
PE161850	MDPZ9216	6/07/2022	Hydrasleeve	90		<0.2	2.7	11	1100					<0.005	3.6	<0.005	0.009	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	56
PE164581	MDPZ9216	19/10/2022	Hydrasleeve	90		<0.2	2.1	12	1100					<0.005	3.8	<0.005	0.005	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	7
PE168102 R0	MDPZ9216	3/05/2023	Hydrasleeve	90		<0.05	2.4	11	1100					<0.005	3.60	<0.005	0.010	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
PE172208.074	MDPZ9216	14/11/2023	Hydrasleeve	90	0.04	<0.05	2.2	12	990					<0.005	3.900	<0.005	0.008	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
PE156870	MDPZ9217	20/11/2021	Airlift			<0.2	1.4	18	530					<0.005	2.1	<0.005	0.021	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	83

Detailed Water Quality Analysis – Groundwater

Lab Report	Bore ID	Sample Date	Sample Type	Sample Depth	Ammonium, NH4	Nitrite-N	Fluoride by ISE	Silicon, Si-Dissolved	Sulfur, S	Iron - Total	Aluminium - Total	Mercury - Total	Manganese - Total	Arsenic, As-Dissolved	Boron, B-Dissolved	Beryllium, Be-Dissolved	Barium, Ba-Dissolved	Cadmium, Cd-Dissolved	Cobalt, Co-Dissolved	Chromium, Cr-Dissolved	Copper, Cu-Dissolved	Molybdenum, Mo- Dissolved	Nickel, Ni-Dissolved	Lead, Pb-Dissolved	Total Suspended Solids (TSS)
					mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
PE157321	MDPZ9217	13/12/2021	Hydrasleeve	30	<0.02			21	370																
PE161850	MDPZ9217	5/07/2022	Hydrasleeve	30		<0.2	2.1	20	420					<0.001	1.3	<0.001	0.02	<0.0001	<0.001	0.007	<0.001	0.001	<0.001	<0.001	64
PE164581	MDPZ9217	23/10/2022	Hydrasleeve	30		<0.2	1.2	23	410					<0.001	1.4	<0.001	0.022	<0.0001	<0.001	0.007	<0.001	0.001	<0.001	<0.001	180
PE168102 R0	MDPZ9217	3/05/2023	Hydrasleeve	30		<0.05	1.2	21	400					<0.001	1.40	<0.001	0.032	<0.0001	<0.001	0.007	<0.001	0.002	<0.001	<0.001	
PE172208.043	MDPZ9217	10/11/2023	Hydrasleeve	30	0.03	<0.05	1.2	23	380					<0.002	1.400	<0.002	0.044	<0.0002	<0.002	0.007	<0.002	<0.002	<0.002	<0.002	
PE156870	MDPZ9218	26/11/2021	Airlift			<0.2	1.1	11	380					<0.002	1.4	<0.002	0.003	<0.0002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	43
PE157321	MDPZ9218	13/12/2021	Hydrasleeve	30	<0.02			12	340																
PE161850	MDPZ9218	5/07/2022	Hydrasleeve	30		<0.2	1.6	20	200					<0.001	0.74	<0.001	0.002	<0.0001	<0.001	0.005	<0.001	<0.001	<0.001	<0.001	70
PE164581	MDPZ9218	23/10/2022	Hydrasleeve	30		<0.2	0.7	24	190					<0.001	0.79	<0.001	0.001	<0.0001	<0.001	0.011	<0.001	<0.001	<0.001	<0.001	270
PE168102 R0	MDPZ9218	2/05/2023	Hydrasleeve	30		0.17	0.9	20	210					<0.001	0.50	<0.001	0.022	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	
PE172208.044	MDPZ9218	11/11/2023	Hydrasleeve	30	0.64	<0.05	1.0	19	260					<0.001	1.000	<0.001	0.018	<0.0001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	
PE172208.075	MDPZ9218	10/11/2023	Hydrasleeve	30	0.53	<0.05	1.0	18	260					0.001	1.000	<0.001	0.014	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	
PE157040	MDPZ9219	30/11/2021	Airlift			<0.2	0.6	22	140					<0.001	0.48	<0.001	0.003	<0.0001	<0.001	0.004	<0.001	<0.001	<0.001	<0.001	11
PE157321	MDPZ9219	13/12/2021	Hydrasleeve	30	<0.02			24	140																
PE161850	MDPZ9219	5/07/2022	Hydrasleeve	30		0.7	1.8	25	230					0.001	0.81	<0.001	0.014	<0.0001	<0.001	0.005	<0.001	<0.001	<0.001	<0.001	52
PE164581	MDPZ9219	24/10/2022	Hydrasleeve	30		<0.2	0.7	26	170					<0.001	0.67	<0.001	0.004	<0.0001	<0.001	0.005	<0.001	<0.001	<0.001	<0.001	6
PE168102 R0	MDPZ9219	2/05/2023	Hydrasleeve	30	0.02	<0.05	0.6	24	160					<0.001	0.39	<0.001	0.022	<0.0001	<0.001	0.005	<0.001	0.005	<0.001	<0.001	
PE172208.045	MDPZ9219	9/11/2023	Hydrasleeve	30	0.02	<0.05	0.6	25	160					<0.001	0.450	<0.001	0.014	<0.0001	<0.001	0.005	<0.001	<0.001	<0.001	<0.001	
PE172208.048	MDPZ9219	9/11/2023	Hydrasleeve	30	0.03	<0.05	0.6	25	160					<0.001	0.480	<0.001	0.009	<0.0001	<0.001	0.005	<0.001	<0.001	<0.001	<0.001	
PE157040	MDPZ9220	6/12/2021	Airlift			<0.2	0.7	16	110					<0.001	0.39	<0.001	0.019	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<5
PE157321	MDPZ9220	13/12/2021	Hydrasleeve	30	<0.02			9.6	94																
PE161850	MDPZ9220	5/07/2022	Hydrasleeve	30		<0.2	0.8	12	92					<0.001	0.35	<0.001	0.03	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	8
PE164581	MDPZ9220	24/10/2022	Hydrasleeve	30		<0.2	0.8	13	97					<0.001	0.41	<0.001	0.03	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	10
PE168102 R0	MDPZ9220	2/05/2023	Hydrasleeve	30		<0.05	0.7	12	110					<0.001	0.27	<0.001	0.040	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	
PE172208.046	MDPZ9220	9/11/2023	Hydrasleeve	30	0.04	<0.05	0.7	10	100					0.001	0.310	<0.001	0.042	<0.0001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	
PE157322	MDPZ9221	12/12/2021	Airlift			<0.2	0.8	25	150					<0.001	0.66	<0.001	0.019	<0.0001	<0.001	0.004	<0.001	<0.001	<0.001	<0.001	9
PE157321	MDPZ9221	14/12/2021	Hydrasleeve	30	<0.02			28	150																
PE161850	MDPZ9221	5/07/2022	Hydrasleeve	30		<0.2	1.1	28	160					0.001	0.65	<0.001	0.015	<0.0001	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	17
PE164581	MDPZ9221	24/10/2022	Hydrasleeve	30		<0.2	0.8	32	160					0.001	0.43	<0.001	0.014	<0.0001	<0.001	0.004	<0.001	<0.001	<0.001	<0.001	<5
PE168102 R0	MDPZ9221	2/05/2023	Hydrasleeve	30		<0.05	0.8	29	160					<0.001	0.45	<0.001	0.017	<0.0001	<0.001	0.004	<0.001	<0.001	<0.001	<0.001	
PE172208.047	MDPZ9221	9/11/2023	Hydrasleeve	30	0.03	<0.05	0.8	30	160					<0.001	0.470	<0.001	0.018	<0.0001	<0.001	0.004	<0.001	<0.001	<0.001	<0.001	
PE172300	MDPZ9222S	21/10/2023	Hydrasleeve	37	<0.02	4	1.5							0.001				<0.001		0.005	0.002		0.001	<0.001	
PE172300	MDPZ9223S	21/10/2023	Hydrasleeve	28	<0.02	5.3	1.5							0.002				<0.001		0.002	<0.001		0.002	<0.001	
PE172300	MDPZ9224D	30/10/2023	Airlift	Airlift	<0.02	3.8	1.3							<0.002				<0.002		0.004	<0.002		<0.002	<0.002	
PE172300	MDPZ9224S	30/10/2023	Airlift	Airlift	<0.02	4.7	1.5							0.002				<0.001		0.004	<0.001		<0.001	<0.001	
PE172300	MDPZ9225	5/11/2023	Airlift	Airlift	<0.02	4.9	1.0							<0.001				<0.001		0.004	<0.001		<0.001	<0.001	

Detailed Water Quality Analysis – Groundwater

Lab Report	Bore ID	Sample Date	Sample Type	Sample Depth	Tin, Sn- Dissolved	Selenium - Dissolved	Selenium - Total	Silver, Ag- Dissolved	Strontium, Sr- Dissolved	Titanium, Ti- Dissolved	Thallium, Tl- Dissolved	Vanadium, V- Dissolved	Zinc - Total	Zinc - Dissolved	Reactive Silica as Metasilicic Acid , Si-H_2SiO3	Chloride as NaCl	Total Kjeldahl Nitrogen	Total Phosphorus
					mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
19-13311	MD5382	4/08/2019	Airlift															
19-19847	MD5382	18/11/2019	Hydrasleeve	45														
20-08048	MD5382	4/05/2020	Hydrasleeve	45			<0.001						<0.01				<0.2	
PE157321	MD5382	12/12/2021	Hydrasleeve	45								<0.001	<0.005					
PE161850	MD5382	5/07/2022	Hydrasleeve	45	<0.001		<0.001	<0.001	0.19	<0.001	<0.001	<0.001	<0.005					
PE164581	MD5382	23/10/2022	Hydrasleeve	45	<0.001	<0.001		<0.001	0.4	<0.001	<0.001	<0.001		<0.005	64	270		
PE168102 R0	MD5382	3/05/2023	Hydrasleeve	45	<0.001	0.001		<0.001	0.36	<0.001	<0.001	<0.001		0.021				
PE172208.051	MD5382	10/11/2023	Hydrasleeve	45	<0.001	<0.001		<0.001	0.470	<0.001	<0.001	<0.001		0.029	52		0.24	
19-13311	MD5455	3/08/2019	Airlift															
19-19847	MD5455	18/11/2019	Hydrasleeve	68														
19-13311	MD5461	3/08/2019	Airlift															
19-19847	MD5461	18/11/2019	Hydrasleeve	65														
20-08048	MD5461	4/05/2020	Hydrasleeve	65			0.002						<0.01				<0.2	
PE157321	MD5461	12/12/2021	Hydrasleeve	50								<0.001	<0.005					
PE161850	MD5461	5/07/2022	Hydrasleeve	65	<0.001		0.002	<0.001	0.66	<0.001	<0.001	<0.001	<0.005					
PE164581	MD5461	23/10/2022	Hydrasleeve	50	<0.001	0.003		<0.001	0.71	<0.001	<0.001	<0.001		<0.005	83	900		
PE168102 R0	MD5461	3/05/2023	Hydrasleeve	50	<0.001	0.003		<0.001	0.61	<0.001	<0.001	<0.001		0.018			1.2	0.14
PE172208.049	MD5461	10/11/2023	Hydrasleeve	50	<0.001	0.004		<0.001	0.710	<0.001	<0.001	0.001		0.023	75		28	
PE172208.050	MD5461 DUP	10/11/2023	Hydrasleeve	50	<0.001	0.003		<0.001	0.570	<0.001	<0.001	<0.001		0.022	76		33	
19-13311	MD6605	4/08/2019	Airlift															
19-19847	MD6605 Lower	18/11/2019	Hydrasleeve	85														
20-08048	MD6605 Lower	4/05/2020	Hydrasleeve	85			<0.001						0.13				0.3	
PE157321	MD6605 Lower	12/12/2021	Hydrasleeve	85								<0.001	0.013					
19-19847	MD6605 Upper	18/11/2019	Hydrasleeve	55														
20-08048	MD6605 Upper	4/05/2020	Hydrasleeve	55			0.051						52				0.4	
PE157321	MD6605 Upper	12/12/2021	Hydrasleeve	55								<0.001	0.01					
PE172208.052	MD6605 Upper	10/11/2023	Hydrasleeve	55	<0.001	0.001		<0.001	0.170	<0.001	<0.001	<0.001		0.049	42		0.25	
PE171616	MDP29215D	28/09/2023	Hydrasleeve	80										<0.010				
PE171616	MDP29215S	28/09/2023	Hydrasleeve	20										<0.005				
PE171616	MDP29223D	30/09/2023	Hydrasleeve	Airlift										<0.010				
19-16376	MDPB0011	19/09/2019	Pumping Test															
19-07588	MDPB0012	8/05/2019	Airlift															
19-16376	MDPB0012	24/09/2019	Pumping Test															
19-07588	MDPB0013	16/05/2019	Airlift															
19-17181	MDPB0013	30/09/2019	Pumping Test															
19-17181	MDPB0014	9/10/2019	Pumping Test															
19-15185	MDPB0015	9/09/2019	Pumping Test															
PE154462	MDPB0016	23/08/2021	Airlift		<0.001	0.003		<0.001	0.57	<0.001	<0.001	<0.001		0.09				
PE157146	MDPB0016	30/11/2021	Pumping Test (Layflat)															
PE154462	MDPB0017	23/08/2021	Airlift		<0.001	0.002		<0.001	0.54	<0.001	<0.001	<0.001		0.033				
PE155569	MDPB0017	13/10/2021	Pumping Test		<0.001	0.002		<0.001	0.52	<0.001	<0.001	<0.001		0.012				
PE154462	MDPB0018	4/09/2021	Airlift		<0.001	0.002		<0.001	0.13	<0.001	<0.001	<0.001		0.17				
PE155297	MDPB0018	30/09/2021	Pumping Test - End		<0.001	0.002		<0.001	0.11	<0.001	<0.001	<0.001		0.11				
PE155018	MDPB0019	10/09/2021	Airlift		<0.001	<0.001		<0.001	0.12	<0.001	<0.001	<0.001		0.046				
PE155569	MDPB0019	8/10/2021	Pumping Test		<0.001	0.001		<0.001	0.12	<0.001	<0.001	<0.001		0.044				
PE156870	MDPB0020	12/11/2021	Airlift		<0.005	0.013		0.047	3	<0.005	<0.005	<0.005		<0.025				
PE157146	MDPB0020	5/12/2021	Pumping Test															
PE157146	MDPB0020	9/12/2021	Pumping Test															
PE172300	MDPB0021 Upper	21/10/2023	Hydrasleeve	67										0.070		2500		
PE172300	MDPB0021 Lower	21/10/2023	Hydrasleeve	122										0.080		3800		
PE172300	MDPB0022	10/10/2023	Hydrasleeve	Airlift										0.011		3600		
PE071720	MDPB004	7/10/2012	Pumping Test															
PE071720	MDPB004	8/10/2012	Pumping Test											0.04				
PE071585	MDPB005	1/10/2012	Pumping Test											0.08				
PE071585	MDPB005	2/10/2012	Pumping Test											0.1				
PE071720	MDPB006	4/10/2012	Pumping Test															
PE071720	MDPB006	5/10/2012	Pumping Test											0.2				
19-08491	MDPZ7449A	31/05/2019	Airlift															
19-19847	MDPZ7449A	16/11/2019	Hydrasleeve	65														
20-08048	MDPZ7449A	2/05/2020	Hydrasleeve	65			<0.001						0.23				0.4	
21-05186	MDPZ7449A	17/03/2021	Hydrasleeve	65														
21-19363	MDPZ7449A	16/10/2021	Hydrasleeve	65														
PE157146	MDPZ7449A	7/12/2021	Hydrasleeve	65														
PE161850	MDPZ7449A	6/07/2022	Hydrasleeve	65	<0.001		<0.001	<0.001	0.42	<0.001	<0.001	<0.001	0.026					
PE164581	MDPZ7449A	26/10/2022	Hydrasleeve	65	<0.001	<0.001		<0.001	0.37	<0.001	<0.001	<0.001		0.026	23	420		
PE168204 R0	MDPZ7449A	4/05/2023	Hydrasleeve	65	<0.001	<0.001		<0.001	0.36	<0.001	<0.001	<0.001		0.052				
PE172208.023	MDPZ7449A	13/11/2023	Hydrasleeve	65	<0.001	0.001		<0.001	0.380	<0.001	<0.001	<0.001		0.037	21			
19-04258	MDPZ7449B	18/03/2019	Airlift															
19-19847	MDPZ7449B	16/11/2019	Hydrasleeve	25														
20-08048	MDPZ7449B	2/05/2020	Hydrasleeve	25			0.001						0.02				<0.2	
21-05186	MDPZ7449B	17/03/2021	Hydrasleeve	25														
21-19363	MDPZ7449B	16/10/2021	Hydrasleeve	25														
PE157146	MDPZ7449B	7/12/2021	Hydrasleeve	25														
PE161850	MDPZ7449B	6/07/2022	Hydrasleeve	25	<0.001		0.002	<0.001	0.4	<0.001	<0.001	0.001	0.006					
PE164581	MDPZ7449B	26/10/2022	Hydrasleeve	25	<0.001	0.003		<0.001	0.35	<0.001	<0.001	0.001		<0.005	92	510		
PE168204 R0	MDPZ7449B	4/05/2023	Hydrasleeve	25	<0.001	<0.001		<0.001	0.37	<0.001	<0.001	0.001		0.023				
PE172208.024	MDPZ7449B	13/11/2023	Hydrasleeve	25	<0.001	0.005		<0.001	0.420	<0.001	<0.001	0.001		0.026	88			
19-13311	MDPZ7449C	11/08/2019	Airlift															
19-19847	MDPZ7449C	16/11/2019	Hydrasleeve	9														
20-08048	MDPZ7449C	2/05/2020	Hydrasleeve	9			0.019						0.01				<0.2	
21-05186	MDPZ7449C	17/03/2021	Hydrasleeve	9														
21-19363	MDPZ7449C	16/10/2021	Hydrasleeve	9														
PE157146	MDPZ7449C	7/12/2021	Hydrasleeve	9														
PE161850	MDPZ7449C	6/07/2022	Hydrasleeve	9	<0.001		0.015	<0.001	1.5	0.001	<0.001	0.007	<0.005					
PE164581	MDPZ7449C	26/10/2022	Hydrasleeve	9	<0.001	0.013		<0.001	1.3	<0.001	<0.001	0.005		<0.005	130	1800		
PE168204 R0	MDPZ7449C	4/05/2023	Hydrasleeve	9	<0.001	0.012		<0.001	1.10	<0.001	<0.001	0.005		0.011			<0.05	
PE172208.021	MDPZ7449C	13/11/2023	Hydrasleeve	9	<0.001	0.005		<0.001	0.390	<0.001	<0.001	0.002		0.300	120		0.22	
PE172208.022	MDPZ7449C_DUP	13/11/2023	Hydrasleeve	9	<0.001	0.017		<0.001	1.200	<0.001	<0.001	0.005		0.019	120		0.16	

Detailed Water Quality Analysis – Groundwater

Lab Report	Bore ID	Sample Date	Sample Type	Sample Depth	Tin, Sn- Dissolved	Selenium - Dissolved	Selenium - Total	Silver, Ag- Dissolved	Strontium, Sr- Dissolved	Titanium, Ti- Dissolved	Thallium, Tl- Dissolved	Vanadium, V- Dissolved	Zinc - Total	Zinc - Dissolved	Reactive Silica as Metasilicic Acid , Si-H_2SiO3	Chloride as NaCl	Total Kjeldahl Nitrogen	Total Phosphorus
					mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
19-08491	MDPZ7450A	30/05/2019	Airlift															
19-19847	MDPZ7450A	18/11/2019	Hydrasleeve	98														
20-08048	MDPZ7450A	2/05/2020	Hydrasleeve	98			<0.001						0.02				<0.2	
21-05186	MDPZ7450A	17/03/2021	Hydrasleeve	98														
21-19363	MDPZ7450A	16/10/2021	Hydrasleeve	98														
PE157146	MDPZ7450A	7/12/2021	Hydrasleeve	98														
PE161850	MDPZ7450A	6/07/2022	Hydrasleeve	98	<0.005		<0.005	0.01	2.4	<0.005	<0.005	<0.005	<0.025					
PE164581	MDPZ7450A	22/10/2022	Hydrasleeve	98	<0.005	<0.005		<0.005	2.1	<0.005	<0.005	<0.005		<0.025	51	3000		
PE168204 R0	MDPZ7450A	4/05/2023	Hydrasleeve	98	<0.002	<0.002		<0.002	1.40	<0.002	<0.002	<0.002		0.011				
PE172208.025	MDPZ7450A	13/11/2023	Hydrasleeve	98	<0.005	0.009		<0.005	1.700	<0.005	<0.005	<0.005		0.031	37			
19-08491	MDPZ7450B	29/05/2019	Airlift															
19-19847	MDPZ7450B	16/11/2019	Hydrasleeve	35														
20-08048	MDPZ7450B	2/05/2020	Hydrasleeve	35			0.001						0.07				<0.2	
21-05186	MDPZ7450B	17/03/2021	Hydrasleeve	35														
21-19363	MDPZ7450B	16/10/2021	Hydrasleeve	35														
PE157146	MDPZ7450B	7/12/2021	Hydrasleeve	35														
PE161850	MDPZ7450B	6/07/2022	Hydrasleeve	35	<0.001		0.002	<0.001	0.46	<0.001	<0.001	0.001	<0.005					
PE164581	MDPZ7450B	22/10/2022	Hydrasleeve	35	<0.001	0.002		<0.001	0.45	<0.001	<0.001	0.001		<0.005	84	250		
PE168204 R0	MDPZ7450B	4/05/2023	Hydrasleeve	35	<0.001	<0.001		<0.001	0.43	<0.001	<0.001	0.001		0.011				
PE172208.026	MDPZ7450B	13/11/2023	Hydrasleeve	35	<0.001	0.003		<0.001	0.460	<0.001	<0.001	0.001		0.023	80			
19-08491	MDPZ7450C	27/05/2019	Airlift															
19-19847	MDPZ7450C	16/11/2019	Hydrasleeve	20														
20-08048	MDPZ7450C	2/05/2020	Hydrasleeve	20			0.001						0.03				0.2	
21-05186	MDPZ7450C	17/03/2021	Hydrasleeve	20														
21-19363	MDPZ7450C	16/10/2021	Hydrasleeve	20														
PE157146	MDPZ7450C	7/12/2021	Hydrasleeve	20														
PE161850	MDPZ7450C	6/07/2022	Hydrasleeve	20	<0.001		0.002	<0.001	0.26	<0.001	<0.001	0.01	<0.005					
PE164581	MDPZ7450C	22/10/2022	Hydrasleeve	20	<0.001	0.002		<0.001	0.23	<0.001	<0.001	0.008		<0.005	93	220		
PE168102 R0	MDPZ7450C	4/05/2023	Hydrasleeve	20	<0.001	<0.001		<0.001	0.42	<0.001	<0.001	0.008		0.011				
PE172208.027	MDPZ7450C	13/11/2023	Hydrasleeve	20	<0.001	0.004		<0.001	0.620	<0.001	<0.001	0.009		0.021	96			
19-12584	MDPZ7451A	17/07/2019	Airlift															
19-19847	MDPZ7451A	16/11/2019	Hydrasleeve	105														
20-08048	MDPZ7451A	2/05/2020	Hydrasleeve	105			<0.001						0.03				0.2	
21-14674	MDPZ7451A	4/08/2021	Hydrasleeve	105														
PE157146	MDPZ7451A	5/12/2021	Hydrasleeve	105														
PE161850	MDPZ7451A	6/07/2022	Hydrasleeve	105	<0.005		<0.005	0.007	4.5	<0.005	<0.005	<0.005	<0.025					
PE164581	MDPZ7451A	22/10/2022	Hydrasleeve	105	<0.005	<0.005		<0.005	4.4	<0.005	<0.005	0.006		<0.025	37	10000		
PE168204 R0	MDPZ7451A	4/05/2023	Hydrasleeve	105	<0.005	<0.005		<0.005	4.30	<0.005	<0.005	<0.005		<0.025				
PE172208.028	MDPZ7451A	13/11/2023	Hydrasleeve	105	<0.005	0.018		<0.005	4.300	<0.005	<0.005	<0.005		0.025	32			
19-04258	MDPZ7451B	17/03/2019	Airlift															
19-19847	MDPZ7451B	16/11/2019	Hydrasleeve	60														
20-08048	MDPZ7451B	2/05/2020	Hydrasleeve	60			0.003						0.05				<0.2	
21-14674	MDPZ7451B	4/08/2021	Hydrasleeve	60														
PE157146	MDPZ7451B	5/12/2021	Hydrasleeve	60														
PE161850	MDPZ7451B	6/07/2022	Hydrasleeve	60	<0.005		0.006	<0.005	2.9	<0.005	<0.005	0.009	<0.025					
PE164581	MDPZ7451B	22/10/2022	Hydrasleeve	60	<0.005	0.009		<0.005	2.9	<0.005	<0.005	0.009		<0.025	67	6600		
PE168204 R0	MDPZ7451B	4/05/2023	Hydrasleeve	60	<0.005	<0.005		<0.005	2.70	<0.005	<0.005	<0.005		<0.025				
PE172208.029	MDPZ7451B	13/11/2023	Hydrasleeve	60	<0.005	0.013		<0.005	2.700	<0.005	<0.005	<0.005		<0.025	57			
19-04258	MDPZ7451C	17/03/2019	Airlift															
19-19847	MDPZ7451C	16/11/2019	Hydrasleeve	20														
20-08048	MDPZ7451C	2/05/2020	Hydrasleeve	20			0.002						0.04				<0.2	
21-14674	MDPZ7451C	4/08/2021	Hydrasleeve	20														
PE157146	MDPZ7451C	5/12/2021	Hydrasleeve	20														
PE161850	MDPZ7451C	6/07/2022	Hydrasleeve	20	<0.001		0.002	<0.001	0.5	<0.001	<0.001	0.003	<0.005					
PE164581	MDPZ7451C	22/10/2022	Hydrasleeve	20	<0.001	0.003		<0.001	0.49	<0.001	<0.001	0.003		0.009	83	1000		
PE168204 R0	MDPZ7451C	4/05/2023	Hydrasleeve	20	<0.001	0.003		<0.001	0.54	<0.001	<0.001	0.003		0.014				
PE172208.030	MDPZ7451C	13/11/2023	Hydrasleeve	20	<0.001	0.004		<0.001	0.530	<0.001	<0.001	0.003		0.017	80			
19-19847	MDPZ7452A	16/11/2019	Hydrasleeve	70														
20-08048	MDPZ7452A	3/05/2020	Hydrasleeve	70			<0.001						0.01				0.4	
21-14674	MDPZ7452A	4/08/2021	Hydrasleeve	70														
PE157146	MDPZ7452A	5/12/2021	Hydrasleeve	70														
PE161850	MDPZ7452A	6/07/2022	Hydrasleeve	70	<0.005		<0.005	<0.005	2.3	<0.005	<0.005	<0.005	<0.025					
PE164581	MDPZ7452A	22/10/2022	Hydrasleeve	70	<0.005	<0.005		<0.005	2.3	<0.005	<0.005	<0.005		<0.025	61	5500		
PE168204 R0	MDPZ7452A	4/05/2023	Hydrasleeve	70	<0.005	<0.005		<0.005	2.30	<0.005	<0.005	<0.005		0.031				
PE172208.031	MDPZ7452A	13/11/2023	Hydrasleeve	70	<0.005	0.008		<0.005	2.300	<0.005	<0.005	<0.005		0.029	56			
19-04258	MDPZ7452B	17/03/2019	Airlift															
19-19847	MDPZ7452B	16/11/2019	Hydrasleeve	45														
20-08048	MDPZ7452B	3/05/2020	Hydrasleeve	45			0.006						<0.01				<0.2	
21-14674	MDPZ7452B	4/08/2021	Hydrasleeve	45														
PE157146	MDPZ7452B	5/12/2021	Hydrasleeve	45														
PE161850	MDPZ7452B	6/07/2022	Hydrasleeve	45	<0.002		0.002	<0.002	1.1	<0.002	<0.002	0.004	<0.01					
PE164581	MDPZ7452B	22/10/2022	Hydrasleeve	45	<0.002	0.008		<0.002	1.1	<0.002	<0.002	0.004		<0.01	100	2600		
PE168204 R0	MDPZ7452B	4/05/2023	Hydrasleeve	45	<0.002	0.005		<0.002	1.10	<0.002	<0.002	0.003		<0.010				
PE172208.032	MDPZ7452B	13/11/2023	Hydrasleeve	45	<0.002	0.009		<0.002	1.200	<0.002	<0.002	0.004		0.022	89			
19-08491	MDPZ7452C	27/05/2019	Airlift															
19-19847	MDPZ7452C	16/11/2019	Hydrasleeve	20														
20-08048	MDPZ7452C	3/05/2020	Hydrasleeve	20			0.006						<0.01				<0.2	
21-14674	MDPZ7452C	4/08/2021	Hydrasleeve	20														
PE157146	MDPZ7452C	5/12/2021	Hydrasleeve	20														
PE161850	MDPZ7452C	6/07/2022	Hydrasleeve	20	<0.002		0.003	<0.002	0.96	<0.002	<0.002	0.004	<0.01					
PE164581	MDPZ7452C	22/10/2022	Hydrasleeve	20	<0.001	0.006		<0.001	0.99	<0.001	<0.001	0.004		<0.005	95	6500		
PE168204 R0	MDPZ7452C	4/05/2023	Hydrasleeve	20	<0.002	<0.002		<0.002	0.94	<0.002	<0.002	0.004		0.010				
PE172208.033	MDPZ7452C	13/11/2023	Hydrasleeve	20	<0.002	0.008		<0.002	0.940	<0.002	<0.002	0.004		0.022	96			
19-15185	MDPZ7453A	6/09/2019	Airlift															
19-19847	MDPZ7453A	16/11/2019	Hydrasleeve	65														
20-08048	MDPZ7453A	3/05/2020	Hydrasleeve	65			0.009						0.09				0.2	
21-14674	MDPZ7453A	4/08/2021	Hydrasleeve	65														
PE157146	MDPZ7453A	5/12/2021	Hydrasleeve	65														

Detailed Water Quality Analysis – Groundwater

Lab Report	Bore ID	Sample Date	Sample Type	Sample Depth	Tin, Sn- Dissolved	Selenium - Dissolved	Selenium - Total	Silver, Ag- Dissolved	Strontium, Sr- Dissolved	Titanium, Ti- Dissolved	Thallium, Tl- Dissolved	Vanadium, V- Dissolved	Zinc - Total	Zinc - Dissolved	Reactive Silica as Metasilicic Acid , Si-H_2SiO3	Chloride as NaCl	Total Kjeldahl Nitrogen	Total Phosphorus
					mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
PE161850	MDPZ7453A	6/07/2022	Hydrasleeve	65	<0.005		0.006	<0.005	4.1	0.005	<0.005	0.012	<0.025					
PE164581	MDPZ7453A	22/10/2022	Hydrasleeve	65	<0.005	0.009		<0.005	4.2	<0.005	<0.005	0.012		<0.025	85	9800		
PE168204 R0	MDPZ7453A	4/05/2023	Hydrasleeve	65	0.060	<0.005		<0.005	4.20	<0.005	<0.005	0.009		0.026				
PE172208.034	MDPZ7453A	13/11/2023	Hydrasleeve	65	<0.005	0.033		<0.005	4.100	<0.005	<0.005	0.006		0.029	83			
19-08491	MDPZ7453B	28/05/2019	Airlift															
19-19847	MDPZ7453B	16/11/2019	Hydrasleeve	40														
20-08048	MDPZ7453B	3/05/2020	Hydrasleeve	40			0.009						0.01				<0.2	
21-14674	MDPZ7453B	4/08/2021	Hydrasleeve	40														
PE157146	MDPZ7453B	5/12/2021	Hydrasleeve	40														
PE161850	MDPZ7453B	6/07/2022	Hydrasleeve	40	<0.005		0.006	<0.005	3.8	<0.005	<0.005	0.057	<0.025					
PE164581	MDPZ7453B	22/10/2022	Hydrasleeve	40	<0.005	0.01		<0.005	3.7	<0.005	<0.005	0.049		<0.025	130	6400		
PE168204 R0	MDPZ7453B	4/05/2023	Hydrasleeve	40	<0.005	0.018		<0.005	3.70	<0.005	<0.005	0.047		<0.025				
PE172208.035	MDPZ7453B	13/11/2023	Hydrasleeve	40	<0.005	0.025		<0.005	3.800	<0.005	<0.005	0.049		<0.025	120			
19-08491	MDPZ7453C	27/05/2019	Airlift															
19-19847	MDPZ7453C	16/11/2019	Hydrasleeve	10														
20-08048	MDPZ7453C	3/05/2020	Hydrasleeve	10			0.01						0.02				<0.2	
21-14674	MDPZ7453C	4/08/2021	Hydrasleeve	10														
PE157146	MDPZ7453C	5/12/2021	Hydrasleeve	10														
PE161850	MDPZ7453C	6/07/2022	Hydrasleeve	10	<0.005		0.01	<0.005	3.9	<0.005	<0.005	0.066	<0.025					
PE164581	MDPZ7453C	22/10/2022	Hydrasleeve	10	<0.005	0.011		<0.005	3.7	<0.005	<0.005	0.066		<0.025	130	6700		
PE168204 R0	MDPZ7453C	4/05/2023	Hydrasleeve	10	<0.005	<0.005		<0.005	3.90	<0.005	<0.005	0.059		<0.025				
PE172208.036	MDPZ7453C	13/11/2023	Hydrasleeve	10	<0.005	0.029		<0.005	3.900	<0.005	<0.005	0.060		0.026	120			
19-19463	MDPZ7454	10/11/2019	Hydrasleeve	50														
20-08048	MDPZ7454	4/05/2020	Hydrasleeve	50			0.002						0.5				<0.2	
21-05186	MDPZ7454	17/03/2021	Hydrasleeve	50														
21-19363	MDPZ7454	16/10/2021	Hydrasleeve	50														
PE157146	MDPZ7454	9/12/2021	Hydrasleeve	50														
PE161850	MDPZ7454	9/07/2022	Hydrasleeve	50	<0.001		<0.001	<0.001	0.056	<0.001	<0.001	<0.001	0.066					
PE164581	MDPZ7454	26/10/2022	Hydrasleeve	50	<0.001	<0.001		<0.001	0.069	<0.001	<0.001	<0.001		0.073	54	150		
PE168102 R0	MDPZ7454	4/05/2023	Hydrasleeve	50	<0.001	0.001		<0.001	0.058	<0.001	<0.001	<0.001		0.063				
PE172208.012	MDPZ7454	12/11/2023	Hydrasleeve	50	<0.001	0.002		<0.001	0.059	<0.001	<0.001	<0.001		0.080	43			
19-19847	MDPZ7455	17/11/2019	Hydrasleeve	50														
20-08048	MDPZ7455	4/05/2020	Hydrasleeve	50			<0.001						0.41				0.5	
21-05186	MDPZ7455	16/03/2021	Hydrasleeve	50														
21-19363	MDPZ7455	16/10/2021	Hydrasleeve	50														
PE157146	MDPZ7455	8/12/2021	Hydrasleeve	50														
PE161850	MDPZ7455	10/07/2022	Hydrasleeve	50	<0.001		<0.001	<0.001	0.048	<0.001	0.003	0.003	0.14					
PE164581	MDPZ7455	26/10/2022	Hydrasleeve	50											100	140		
PE168204 R0	MDPZ7455	5/05/2023	Hydrasleeve	50	<0.001	<0.001		<0.001	0.04	<0.001	0.002	0.003		0.180			0.25	
19-15185	MDPZ7456A	5/09/2019	Airlift															
19-19847	MDPZ7456A	17/11/2019	Hydrasleeve	105														
20-08048	MDPZ7456A	4/05/2020	Hydrasleeve	105			<0.001						0.05				0.3	
21-05186	MDPZ7456A	16/03/2021	Hydrasleeve	105														
PE157146	MDPZ7456A	7/12/2021	Hydrasleeve	105														
PE161850	MDPZ7456A	9/07/2022	Hydrasleeve	105	<0.001		<0.001	<0.001	0.55	<0.001	<0.001	0.007	<0.005					
PE164581	MDPZ7456A	26/10/2022	Hydrasleeve	105											65	1400		
PE168204 R0	MDPZ7456A	5/05/2023	Hydrasleeve	105	<0.001	<0.001		<0.001	0.58	<0.001	<0.001	0.004		0.010				
PE172208.013	MDPZ7456A	13/11/2023	Hydrasleeve	105	<0.001	0.004		<0.001	0.560	<0.001	<0.001	0.005		0.015	62			
19-08491	MDPZ7456B	29/05/2019	Airlift															
19-19847	MDPZ7456B	17/11/2019	Hydrasleeve	55														
20-08048	MDPZ7456B	4/05/2020	Hydrasleeve	55			0.002						<0.01				2	
21-05186	MDPZ7456B	16/03/2021	Hydrasleeve	55														
PE157146	MDPZ7456B	7/12/2021	Hydrasleeve	55														
PE161850	MDPZ7456B	9/07/2022	Hydrasleeve	55	<0.001		0.003	<0.001	0.71	<0.001	<0.001	<0.001	<0.005					
PE164581	MDPZ7456B	26/10/2022	Hydrasleeve	55											83	1600		
PE168204 R0	MDPZ7456B	5/05/2023	Hydrasleeve	55	<0.001	0.002		<0.001	0.70	<0.001	<0.001	<0.001		0.015				
PE172208.014	MDPZ7456B	13/11/2023	Hydrasleeve	55	<0.001	0.004		<0.001	0.690	<0.001	<0.001	<0.001		0.022	79			
19-08491	MDPZ7456C	27/05/2019	Airlift															
19-19847	MDPZ7456C	17/11/2019	Hydrasleeve	20														
20-08048	MDPZ7456C	4/05/2020	Hydrasleeve	20			0.003						0.03				<0.2	
21-05186	MDPZ7456C	16/03/2021	Hydrasleeve	20														
PE157146	MDPZ7456C	7/12/2021	Hydrasleeve	20														
PE161850	MDPZ7456C	9/07/2022	Hydrasleeve	20	<0.001		0.004	<0.001	0.72	<0.001	<0.001	0.004	<0.005					
PE164581	MDPZ7456C	26/10/2022	Hydrasleeve	20											100	1200		
PE168204 R0	MDPZ7456C	5/05/2023	Hydrasleeve	20	<0.001	0.004		<0.001	0.80	<0.001	<0.001	0.004		0.012				
PE172208.015	MDPZ7456C	13/11/2023	Hydrasleeve	20	<0.001	0.005		<0.001	0.650	<0.001	<0.001	0.002		0.024	96			
PE172208.001	MDPZ7457_DUP	12/11/2023	Hydrasleeve	28	<0.001	0.010		<0.001	1.100	<0.001	<0.001	0.011		0.017	98		0.11	
19-04258	MDPZ7457A	13/03/2019	Airlift															
19-19463	MDPZ7457A	13/11/2019	Hydrasleeve	90														
20-08048	MDPZ7457A	2/05/2020	Hydrasleeve	90			0.003						<0.01				<0.2	
21-14674	MDPZ7457A	4/08/2021	Hydrasleeve	90														
PE157146	MDPZ7457A	2/12/2021	Hydrasleeve	90														
PE161850	MDPZ7457A	7/07/2022	Hydrasleeve	90	<0.005		0.005	<0.005	2.6	<0.005	<0.005	<0.005	<0.025					
PE164581	MDPZ7457A	26/10/2022	Hydrasleeve	90	<0.005	<0.005		<0.005	2.5	<0.005	<0.005	<0.005		<0.025	25	6700		
PE168204 R0	MDPZ7457A	4/05/2023	Hydrasleeve	90	<0.005	<0.005		0.009	2.50	<0.005	<0.005	<0.005		<0.025				
PE172208.060	MDPZ7457A	12/11/2023	Hydrasleeve	90	<0.005	0.009		<0.005	2.600	<0.005	<0.005	<0.005		<0.025	24			
19-04258	MDPZ7457B	14/03/2019	Airlift															
19-19463	MDPZ7457B	13/11/2019	Hydrasleeve	45														
20-08048	MDPZ7457B	2/05/2020	Hydrasleeve	45			0.005						0.02				<0.2	
21-14674	MDPZ7457B	4/08/2021	Hydrasleeve	45														
PE157146	MDPZ7457B	2/12/2021	Hydrasleeve	45														
PE161850	MDPZ7457B	7/07/2022	Hydrasleeve	45	<0.005		<0.005	<0.005	1.7	<0.005	<0.005	0.006	<0.025					
PE164581	MDPZ7457B	26/10/2022	Hydrasleeve	45	<0.005	0.006		<0.005	1.8	<0.005	<0.005	0.007		<0.025	87	5000		
PE168204 R0	MDPZ7457B	5/05/2023	Hydrasleeve	45	<0.002	0.005		0.004	1.80	0.002	<0.002	0.004		<0.010				
PE172208.061	MDPZ7457B	12/11/2023	Hydrasleeve	45	<0.005	0.008		<0.005	1.900	<0.005	<0.005	0.006		0.046	81			
19-04258	MDPZ7457C	16/03/2019	Airlift															
19-19463	MDPZ7457C	13/11/2019	Hydrasleeve	28														
20-08048	MDPZ7457C	2/05/2020	Hydrasleeve	28			0.004						0.01				0.4	

Detailed Water Quality Analysis – Groundwater

Lab Report	Bore ID	Sample Date	Sample Type	Sample Depth	Tin, Sn- Dissolved	Selenium - Dissolved	Selenium - Total	Silver, Ag- Dissolved	Strontium, Sr- Dissolved	Titanium, Ti- Dissolved	Thallium, Tl- Dissolved	Vanadium, V- Dissolved	Zinc - Total	Zinc - Dissolved	Reactive Silica as Metasilicic Acid , Si-H_2SiO3	Chloride as NaCl	Total Kjeldahl Nitrogen	Total Phosphorus
					mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
21-14674	MDPZ7457C	4/08/2021	Hydrasleeve	28														
PE157146	MDPZ7457C	2/12/2021	Hydrasleeve	28														
PE161850	MDPZ7457C	7/07/2022	Hydrasleeve	28	<0.002		0.003	<0.002	1.1	<0.002	<0.002	0.014	<0.01					
PE164581	MDPZ7457C	26/10/2022	Hydrasleeve	28	<0.001	0.005		<0.001	1.1	0.001	<0.001	0.011		<0.005	110	2800		
PE168204 R0	MDPZ7457C	5/05/2023	Hydrasleeve	28	<0.002	0.006		<0.002	1.10	<0.002	<0.002	0.009		0.020			<0.05	
PE172208.062	MDPZ7457C DUP	12/11/2023	Hydrasleeve	28	<0.005	0.007		<0.005	1.100	<0.005	<0.005	0.010		<0.025	98		0.10	
19-04258	MDPZ7458A	15/03/2019	Airlift															
19-19463	MDPZ7458A	13/11/2019	Hydrasleeve	68														
20-08048	MDPZ7458A	2/05/2020	Hydrasleeve	68			0.01						0.01				<0.2	
21-14674	MDPZ7458A	5/08/2021	Hydrasleeve	68														
PE157146	MDPZ7458A	4/12/2021	Hydrasleeve	68														
PE161850	MDPZ7458A	7/07/2022	Hydrasleeve	68	<0.005		0.013	<0.005	2.4	<0.005	<0.005	<0.005	<0.025					
PE164581	MDPZ7458A	23/10/2022	Hydrasleeve	68	<0.005	0.008		<0.005	2	<0.005	<0.005	<0.005		<0.025	63	5700		
PE168204 R0	MDPZ7458A	4/05/2023	Hydrasleeve	68	<0.005	0.012		<0.005	2.20	<0.005	<0.005	<0.005		<0.025				
PE172208.057	MDPZ7458A	12/11/2023	Hydrasleeve	68	<0.005	0.018		<0.005	2.300	<0.005	<0.005	<0.005		<0.025	56			
19-04258	MDPZ7458B	16/03/2019	Airlift															
19-19463	MDPZ7458B	13/11/2019	Hydrasleeve	50														
20-08048	MDPZ7458B	2/05/2020	Hydrasleeve	50			0.011						0.02				0.2	
21-14674	MDPZ7458B	5/08/2021	Hydrasleeve	50														
PE157146	MDPZ7458B	4/12/2021	Hydrasleeve	50														
PE161850	MDPZ7458B	7/07/2022	Hydrasleeve	50	<0.005		0.016	<0.005	2.7	<0.005	<0.005	0.007	<0.025					
PE164581	MDPZ7458B	23/10/2022	Hydrasleeve	50	<0.005	0.013		<0.005	2.3	<0.005	<0.005	0.006		<0.025	73	6200		
PE168204 R0	MDPZ7458B	4/05/2023	Hydrasleeve	50	<0.005	0.012		<0.005	2.30	<0.005	<0.005	<0.005		<0.025				
PE172208.058	MDPZ7458B	12/11/2023	Hydrasleeve	50	<0.005	0.018		<0.005	2.500	<0.005	<0.005	0.006		<0.025	66			
19-04258	MDPZ7458C	16/03/2019	Airlift															
19-19463	MDPZ7458C	13/11/2019	Hydrasleeve	8														
20-08048	MDPZ7458C	2/05/2020	Hydrasleeve	8			0.009						0.01				<0.2	
21-14674	MDPZ7458C	5/08/2021	Hydrasleeve	8														
PE157146	MDPZ7458C	5/12/2021	Hydrasleeve	8														
PE164581	MDPZ7458C	23/10/2022	Hydrasleeve	8	<0.005	0.01		<0.005	1.8	<0.005	<0.005	0.03		<0.025	130	5600		
PE168204 R0	MDPZ7458C	4/05/2023	Hydrasleeve	8	<0.005	<0.005		<0.005	1.70	<0.005	<0.005	0.029		<0.025				
PE172208.059	MDPZ7458C	12/11/2023	Hydrasleeve	8	<0.005	0.014		<0.005	1.800	<0.005	<0.005	0.030		<0.025	120			
19-04258	MDPZ7459	18/03/2019	Airlift															
19-19463	MDPZ7459	12/11/2019	Hydrasleeve	20														
20-08048	MDPZ7459	3/05/2020	Hydrasleeve	20			0.001						0.02				<0.2	
21-05186	MDPZ7459	17/03/2021	Hydrasleeve	20														
PE157146	MDPZ7459	6/12/2021	Hydrasleeve	20														
PE161850	MDPZ7459	6/07/2022	Hydrasleeve	20	<0.001		0.001	<0.001	0.28	<0.001	<0.001	0.011	<0.005					
PE164581	MDPZ7459	21/10/2022	Hydrasleeve	20	<0.001	<0.001		<0.001	0.28	<0.001	<0.001	0.011		<0.005	110	63		
PE168204 R0	MDPZ7459	4/05/2023	Hydrasleeve	20	<0.001	0.003		<0.001	0.36	<0.001	<0.001	0.012		0.026				
PE172208.037	MDPZ7459	12/11/2023	Hydrasleeve	20	<0.001	0.002		<0.001	0.400	<0.001	<0.001	0.013		0.041	130			
19-08491	MDPZ7460A	30/05/2019	Airlift															
19-19463	MDPZ7460A	13/11/2019	Hydrasleeve	85														
20-08048	MDPZ7460A	2/05/2020	Hydrasleeve	85			<0.001						0.02				0.4	
21-05186	MDPZ7460A	17/03/2021	Hydrasleeve	85														
PE157146	MDPZ7460A	7/12/2021	Hydrasleeve	85														
PE161850	MDPZ7460A	9/07/2022	Hydrasleeve	85	<0.001		<0.001	<0.001	0.92	0.001	<0.001	<0.001	<0.005					
PE164581	MDPZ7460A	26/10/2022	Hydrasleeve	85											37	2700		
PE168204 R0	MDPZ7460A	5/05/2023	Hydrasleeve	85	<0.001	<0.001		<0.001	0.80	<0.001	<0.001	<0.001		<0.005				
PE172208.009	MDPZ7460A	12/11/2023	Hydrasleeve	85	<0.001	0.003		<0.001	0.920	<0.001	<0.001	<0.001		0.018	35			
19-08491	MDPZ7460B	29/05/2019	Airlift															
19-19463	MDPZ7460B	13/11/2019	Hydrasleeve	49														
20-08048	MDPZ7460B	2/05/2020	Hydrasleeve	49			0.002						0.01				<0.2	
21-05186	MDPZ7460B	17/03/2021	Hydrasleeve	49														
PE157146	MDPZ7460B	7/12/2021	Hydrasleeve	49														
PE161850	MDPZ7460B	9/07/2022	Hydrasleeve	49	<0.001		0.004	<0.001	0.8	<0.001	<0.001	<0.001	<0.005					
PE164581	MDPZ7460B	26/10/2022	Hydrasleeve	49											84	1900		
PE168204 R0	MDPZ7460B	5/05/2023	Hydrasleeve	49	<0.001	0.003		<0.001	0.81	<0.001	<0.001	<0.001	0.009	0.000				
PE172208.010	MDPZ7460B	12/11/2023	Hydrasleeve	49	<0.001	0.005		<0.001	0.800	<0.001	<0.001	0.001		0.021	78			
19-08491	MDPZ7460C	26/05/2019	Airlift															
19-19463	MDPZ7460C	13/11/2019	Hydrasleeve	25														
20-08048	MDPZ7460C	2/05/2020	Hydrasleeve	25			0.002						<0.01				<0.2	
21-05186	MDPZ7460C	17/03/2021	Hydrasleeve	25														
PE157146	MDPZ7460C	7/12/2021	Hydrasleeve	25														
PE161850	MDPZ7460C	9/07/2022	Hydrasleeve	25	<0.001		0.002	<0.001	0.84	<0.001	<0.001	0.003	<0.005					
PE164581	MDPZ7460C	26/10/2022	Hydrasleeve	25											89	1900		
PE168102 R0	MDPZ7460C	4/05/2023	Hydrasleeve	25	<0.001	0.004		<0.001	0.77	<0.001	<0.001	0.003		0.008				
PE172208.011	MDPZ7460C	12/11/2023	Hydrasleeve	25	<0.001	0.005		<0.001	0.820	<0.001	<0.001	0.002		0.008	84			
20-08574	MDPZ7461	10/05/2020	Hydrasleeve	20														
21-14674	MDPZ7461	5/08/2021	Hydrasleeve	20														
PE157146	MDPZ7461	5/12/2021	Hydrasleeve	20														
PE161850	MDPZ7461	7/07/2022	Hydrasleeve	20	<0.001		0.005	0.001	1	<0.001	<0.001	0.004	<0.005					
PE164581	MDPZ7461	23/10/2022	Hydrasleeve	20	<0.001	0.006		<0.001	0.97	<0.001	<0.001	0.002		<0.005	98	2600		
PE168204 R0	MDPZ7461	4/05/2023	Hydrasleeve	20	<0.001	0.003		<0.001	0.97	<0.001	<0.001	0.003		0.011				
PE172208.053	MDPZ7461	12/11/2023	Hydrasleeve	20	<0.002	0.011		<0.002	1.000	<0.002	<0.002	0.003		0.019	93			
19-04524	MDPZ7462A	22/03/2019	Airlift															
19-19463	MDPZ7462A	12/11/2019	Hydrasleeve	115														
20-08048	MDPZ7462A	3/05/2020	Hydrasleeve	115			<0.001						0.04				1.1	
19-04524	MDPZ7462B	22/03/2019	Airlift															
19-19463	MDPZ7462B	12/11/2019	Hydrasleeve	55														
20-08048	MDPZ7462B	3/05/2020	Hydrasleeve	55			0.006						0.05				<0.2	
19-04524	MDPZ7462C	22/03/2019	Airlift															
19-19463	MDPZ7462C	12/11/2019	Hydrasleeve	30														
20-08048	MDPZ7462C	3/05/2020	Hydrasleeve	30			0.005						<0.01				<0.2	
19-05368	MDPZ7463	1/04/2019	Airlift															
19-19463	MDPZ7463 Lower	12/11/2019	Hydrasleeve	80														
20-08048	MDPZ7463 Lower	4/05/2020	Hydrasleeve	80			0.005						0.03				<0.2	
21-05186	MDPZ7463 Lower	17/03/2021	Hydrasleeve	80														

Detailed Water Quality Analysis – Groundwater

Lab Report	Bore ID	Sample Date	Sample Type	Sample Depth	Tin, Sn- Dissolved	Selenium - Dissolved	Selenium - Total	Silver, Ag- Dissolved	Strontium, Sr- Dissolved	Titanium, Ti- Dissolved	Thallium, Tl- Dissolved	Vanadium, V- Dissolved	Zinc - Total	Zinc - Dissolved	Reactive Silica as Metasilicic Acid , Si-H_2SiO3	Chloride as NaCl	Total Kjeldahl Nitrogen	Total Phosphorus
					mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
PE157146	MDPZ7463 Lower	1/12/2021	Hydrasleeve	80														
PE161850	MDPZ7463 Lower	6/07/2022	Hydrasleeve	80	<0.001		0.005	0.001	1.8	0.001	<0.001	0.002	0.007					
PE164581	MDPZ7463 Lower	21/10/2022	Hydrasleeve	80	N.A.	N.A.		N.A.	N.A.	N.A.	N.A.	N.A.		N.A.	79	2800		
PE172208.039	MDPZ7463 Lower	12/11/2023	Hydrasleeve	80	<0.001	0.004		<0.001	1.200	<0.001	<0.001	0.003		0.020	66			
19-19463	MDPZ7463 Upper	12/11/2019	Hydrasleeve	15														
20-08048	MDPZ7463 Upper	4/05/2020	Hydrasleeve	15			0.003						0.01				<0.2	
21-05186	MDPZ7463 Upper	17/03/2021	Hydrasleeve	15														
PE157146	MDPZ7463 Upper	1/12/2021	Hydrasleeve	15														
PE161850	MDPZ7463 Upper	6/07/2022	Hydrasleeve	15	<0.001		0.003	<0.001	0.91	<0.001	<0.001	0.005	<0.005					
PE164581	MDPZ7463 Upper	21/10/2022	Hydrasleeve	15	<0.001	0.003		<0.001	0.98	<0.001	<0.001	0.005		<0.005	86	1300		
PE172208.038	MDPZ7463 Upper	12/11/2023	Hydrasleeve	15	<0.001	0.006		<0.001	0.970	<0.001	<0.001	0.004		0.020	82			
PE168102 R0	MDPZ7463D	3/05/2023	Hydrasleeve	80	<0.001	0.008		<0.001	1.60	<0.001	<0.001	0.003		0.021				
PE168102 R0	MDPZ7463S	3/05/2023	Hydrasleeve	15	<0.001	0.002		<0.001	0.86	<0.001	<0.001	0.004		0.033				
19-05776	MDPZ7464	5/04/2019	Airlift															
19-19463	MDPZ7464 Lower	12/11/2019	Hydrasleeve	85														
20-08048	MDPZ7464 Lower	3/05/2020	Hydrasleeve	85			0.001						0.09				0.2	
21-05186	MDPZ7464 Lower	16/03/2021	Hydrasleeve	85														
PE157146	MDPZ7464 Lower	6/12/2021	Hydrasleeve	85														
PE161850	MDPZ7464 Lower	6/07/2022	Hydrasleeve	85	<0.005		<0.005	0.021	3.2	<0.005	<0.005	<0.005	0.039					
PE164581	MDPZ7464 Lower	21/10/2022	Hydrasleeve	80	<0.005	<0.005		<0.005	2.9	<0.005	<0.005	<0.005		<0.025	56	3400		
PE172208.041	MDPZ7464 Lower	12/11/2023	Hydrasleeve	80	<0.002	<0.002		<0.002	1.300	<0.002	<0.002	0.004		0.043	30			
19-19463	MDPZ7464 Upper	12/11/2019	Hydrasleeve	15														
20-08048	MDPZ7464 Upper	3/05/2020	Hydrasleeve	15			0.001						0.05				<0.2	
21-05186	MDPZ7464 Upper	16/03/2021	Hydrasleeve	15														
PE157146	MDPZ7464 Upper	6/12/2021	Hydrasleeve	15														
PE161850	MDPZ7464 Upper	6/07/2022	Hydrasleeve	15	<0.001		0.002	<0.001	0.5	<0.001	<0.001	0.007	<0.005					
PE164581	MDPZ7464 Upper	21/10/2022	Hydrasleeve	15	<0.001	0.001		<0.001	0.32	<0.001	<0.001	0.006		<0.005	82	240		
PE172208.040	MDPZ7464 Upper	12/11/2023	Hydrasleeve	15	<0.001	0.003		<0.001	0.320	<0.001	<0.001	0.006		0.020	84			
PE168102 R0	MDPZ7464D	3/05/2023	Hydrasleeve	80	<0.005	<0.005		<0.005	3.20	<0.005	<0.005	<0.005		0.055				
PE168102 R0	MDPZ7464S	3/05/2023	Hydrasleeve	15	<0.001	0.002		<0.001	0.29	<0.001	<0.001	0.005		0.020				
19-05776	MDPZ7465	9/04/2019	Airlift															
20-08574	MDPZ7465	10/05/2020	Hydrasleeve	90														
PE161850	MDPZ7465	9/07/2022	Hydrasleeve	90	<0.001		<0.001	<0.001	0.29	<0.001	<0.001	<0.001	<0.005					
PE164581	MDPZ7465	26/10/2022	Hydrasleeve	90											66	730		
PE168204 R0	MDPZ7465	5/05/2023	Hydrasleeve	90	<0.001	<0.001		<0.001	0.26	<0.001	<0.001	<0.001		0.012			0.38	
PE172208.017	MDPZ7465	13/11/2023	Hydrasleeve	90	<0.001	0.001		<0.001	0.220	<0.001	<0.001	<0.001		0.012	53		0.61	
PE172208.018	MDPZ7465_DUP	13/11/2023	Hydrasleeve	90	<0.001	0.001		<0.001	0.220	<0.001	<0.001	<0.001		0.021	53		0.53	
19-06249	MDPZ7466	26/04/2019	Airlift															
19-19847	MDPZ7466 Lower	17/11/2019	Hydrasleeve	60														
20-08048	MDPZ7466 Lower	4/05/2020	Hydrasleeve	60			<0.001						0.4				0.5	
21-05186	MDPZ7466 Lower	16/03/2021	Hydrasleeve	60														
PE157146	MDPZ7466 Lower	8/12/2021	Hydrasleeve	60														
PE161850	MDPZ7466 Lower	9/07/2022	Hydrasleeve	60	<0.001		<0.001	<0.001	0.14	<0.001	0.022	<0.001	0.37					
PE164581	MDPZ7466 Lower	26/10/2022	Hydrasleeve	60	N.A.	N.A.		N.A.	N.A.	N.A.	N.A.	N.A.		N.A.	110	250		
19-19847	MDPZ7466 Upper	17/11/2019	Hydrasleeve	40														
20-08048	MDPZ7466 Upper	4/05/2020	Hydrasleeve	40			<0.001						0.04				0.2	
21-05186	MDPZ7466 Upper	16/03/2021	Hydrasleeve	40														
PE157146	MDPZ7466 Upper	8/12/2021	Hydrasleeve	40														
PE161850	MDPZ7466 Upper	9/07/2022	Hydrasleeve	40	<0.001		<0.001	<0.001	0.086	<0.001	<0.001	<0.001	<0.005					
PE164581	MDPZ7466 Upper	26/10/2022	Hydrasleeve	40	N.A.	N.A.		N.A.	N.A.	N.A.	N.A.	N.A.		N.A.	79	74		
PE168204 R0	MDPZ7466D	5/05/2023	Hydrasleeve	60	<0.001	<0.001		<0.001	0.10	<0.001	0.008	<0.001		0.220				
PE172208.020	MDPZ7466D	14/11/2023	Hydrasleeve	60	<0.001	0.001		<0.001	0.130	<0.001	0.022	<0.001		0.380	98			
PE168204 R0	MDPZ7466S	5/05/2023	Hydrasleeve	40	<0.001	0.001		<0.001	0.08	<0.001	<0.001	<0.001		0.034				
PE172208.019	MDPZ7466S	14/11/2023	Hydrasleeve	40	<0.001	0.001		<0.001	0.073	<0.001	<0.001	<0.001		0.035	74			
19-06249	MDPZ7467	26/04/2019	Airlift															
19-19847	MDPZ7467 Lower	17/11/2019	Hydrasleeve	62														
20-08048	MDPZ7467 Lower	4/05/2020	Hydrasleeve	62			<0.001						0.3				0.3	
21-05186	MDPZ7467 Lower	16/03/2021	Hydrasleeve	62														
PE157146	MDPZ7467 Lower	8/12/2021	Hydrasleeve	62														
PE161850	MDPZ7467 Lower	10/07/2022	Hydrasleeve	62	<0.001		<0.001	<0.001	0.27	<0.001	<0.001	<0.001	0.063					
PE164581	MDPZ7467 Lower	26/10/2022	Hydrasleeve	62	N.A.	N.A.		N.A.	N.A.	N.A.	N.A.	N.A.		N.A.	37	250		
19-19847	MDPZ7467 Upper	17/11/2019	Hydrasleeve	50														
20-08048	MDPZ7467 Upper	4/05/2020	Hydrasleeve	50			<0.001						0.51				0.6	
21-05186	MDPZ7467 Upper	16/03/2021	Hydrasleeve	50														
PE157146	MDPZ7467 Upper	8/12/2021	Hydrasleeve	50														
PE161850	MDPZ7467 Upper	10/07/2022	Hydrasleeve	50	<0.001		<0.001	<0.001	0.17	<0.001	<0.001	<0.001	0.21					
PE164581	MDPZ7467 Upper	26/10/2022	Hydrasleeve	50	N.A.	N.A.		N.A.	N.A.	N.A.	N.A.	N.A.		N.A.	42	210		
PE168204 R0	MDPZ7467D	5/05/2023	Hydrasleeve	62	<0.001	<0.001		<0.001	0.24	<0.001	<0.001	<0.001		0.068				
PE172208.064	MDPZ7467D	14/11/2023	Hydrasleeve	62	<0.001	<0.001		<0.001	0.270	<0.001	<0.001	<0.001		0.073	34			
PE168204 R0	MDPZ7467S	5/05/2023	Hydrasleeve	50	<0.001	<0.001		<0.001	0.15	<0.001	<0.001	<0.001		0.260				
PE172208.063	MDPZ7467S	14/11/2023	Hydrasleeve	50	<0.001	<0.001		<0.001	0.150	<0.001	<0.001	<0.001		0.210	38			
19-06249	MDPZ7468A	26/04/2019	Airlift															
19-19463	MDPZ7468A	12/11/2019	Hydrasleeve	85														
20-08048	MDPZ7468A	3/05/2020	Hydrasleeve	85			<0.001						0.01				0.2	
21-14674	MDPZ7468A	5/08/2021	Hydrasleeve	85														
PE157146	MDPZ7468A	1/12/2021	Hydrasleeve	85														
PE161850	MDPZ7468A	6/07/2022	Hydrasleeve	62	<0.005		<0.005	<0.005	4.1	<0.005	<0.005	<0.005	<0.025					
PE164581	MDPZ7468A	21/10/2022	Hydrasleeve	85	<0.005	<0.005		<0.005	4.1	<0.005	<0.005	<0.005		<0.025	19	10000		
PE168102 R0	MDPZ7468A	3/05/2023	Hydrasleeve	85	<0.010	<0.010		<0.010	4.00	<0.010	<0.010	<0.010		<0.050				
PE172208.065	MDPZ7468A	12/11/2023	Hydrasleeve	85	<0.005	0.012		<0.005	3.600	<0.005	<0.005	<0.005		0.037	24			
19-06249	MDPZ7468B	26/04/2019	Airlift															
19-19463	MDPZ7468B	12/11/2019	Hydrasleeve	60														
20-08048	MDPZ7468B	3/05/2020	Hydrasleeve	60			0.006						0.01				<0.2	
21-14674	MDPZ7468B	5/08/2021	Hydrasleeve	60														
PE157146	MDPZ7468B	1/12/2021	Hydrasleeve	60														
PE161850	MDPZ7468B	6/07/2022	Hydrasleeve	50	<0.005		<0.005	<0.005	3.2	<0.005	<0.005	<0.005	<0.025					
PE164581	MDPZ7468B	21/10/2022	Hydrasleeve	60	<0.001	0.007		0.003	3.1	0.002	<0.001	0.002		<0.005	67	6400		
PE168102 R0	MDPZ7468B	3/05/2023	Hydrasleeve	60	<0.005	<0.005		<0.005	3.10	<0.005	<0.005	<0.005		<0.025				

Detailed Water Quality Analysis – Groundwater

Lab Report	Bore ID	Sample Date	Sample Type	Sample Depth	Tin, Sn- Dissolved	Selenium - Dissolved	Selenium - Total	Silver, Ag- Dissolved	Strontium, Sr- Dissolved	Titanium, Ti- Dissolved	Thallium, Tl- Dissolved	Vanadium, V- Dissolved	Zinc - Total	Zinc - Dissolved	Reactive Silica as Metasilicic Acid , Si-H_2SiO3	Chloride as NaCl	Total Kjeldahl Nitrogen	Total Phosphorus
					mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
PE172208.066	MDPZ7468B	12/11/2023	Hydrasleeve	60	<0.005	0.013		<0.005	3.100	<0.005	<0.005	<0.005		0.026	63			
19-06249	MDPZ7468C	26/04/2019	Airlift															
19-19463	MDPZ7468C	13/11/2019	Hydrasleeve	30														
20-08048	MDPZ7468C	3/05/2020	Hydrasleeve	30			0.005						0.12				<0.2	
21-14674	MDPZ7468C	5/08/2021	Hydrasleeve	30														
PE157146	MDPZ7468C	1/12/2021	Hydrasleeve	30														
PE161850	MDPZ7468C	6/07/2022	Hydrasleeve	85	<0.005		<0.005	0.019	2.1	<0.005	<0.005	<0.005	<0.025					
PE164581	MDPZ7468C	21/10/2022	Hydrasleeve	30	<0.002	0.004		<0.002	2.2	<0.002	<0.002	0.003		<0.01	69	4200		
PE168102 R0	MDPZ7468C	3/05/2023	Hydrasleeve	30	<0.005	0.006		<0.005	2.00	<0.005	<0.005	<0.005		0.026				
PE172208.067	MDPZ7468C	12/11/2023	Hydrasleeve	30	<0.005	0.010		<0.005	2.200	<0.005	<0.005	<0.005		0.037	61			
19-06460	MDPZ7469A	29/04/2019	Airlift															
19-19463	MDPZ7469A	13/11/2019	Hydrasleeve	100														
20-08048	MDPZ7469A	2/05/2020	Hydrasleeve	100			0.002						0.36				0.2	
21-05186	MDPZ7469A	16/03/2021	Hydrasleeve	100														
PE161850	MDPZ7469A	8/07/2022	Hydrasleeve	60	<0.005		<0.005	0.011	2.3	<0.005	<0.005	<0.005	0.061					
PE164581	MDPZ7469A	26/10/2022	Hydrasleeve	100	<0.005	<0.005		<0.005	2.1	<0.005	<0.005	<0.005		0.033	29	6700		
PE168204 R0	MDPZ7469A	5/05/2023	Hydrasleeve	100	<0.005	<0.005		<0.005	2.10	<0.005	<0.005	<0.005		<0.025				
PE172208.002	MDPZ7469A	12/11/2023	Hydrasleeve	100	<0.005	0.010		<0.005	2.400	<0.005	<0.005	<0.005		0.086	21			
19-06460	MDPZ7469B	29/04/2019	Airlift															
19-19463	MDPZ7469B	13/11/2019	Hydrasleeve	75														
20-08048	MDPZ7469B	2/05/2020	Hydrasleeve	75			0.003						0.02				<0.2	
21-05186	MDPZ7469B	16/03/2021	Hydrasleeve	75														
PE161850	MDPZ7469B	8/07/2022	Hydrasleeve	30	<0.001		0.003	<0.001	0.6	<0.001	<0.001	<0.001	<0.005					
PE164581	MDPZ7469B	26/10/2022	Hydrasleeve	75	<0.001	0.002		<0.001	0.61	<0.001	<0.001	<0.001		<0.005	85	1200		
PE168204 R0	MDPZ7469B	5/05/2023	Hydrasleeve	75	<0.001	0.004		<0.001	0.59	<0.001	<0.001	<0.001		0.016				
PE172208.003	MDPZ7469B	12/11/2023	Hydrasleeve	75	<0.001	0.005		<0.001	0.600	<0.001	<0.001	<0.001		0.023	79			
19-06460	MDPZ7469C	29/04/2019	Airlift															
19-19463	MDPZ7469C	13/11/2019	Hydrasleeve	35														
20-08048	MDPZ7469C	2/05/2020	Hydrasleeve	35			0.002						0.02				<0.2	
21-05186	MDPZ7469C	16/03/2021	Hydrasleeve	35														
PE161850	MDPZ7469C	8/07/2022	Hydrasleeve	100	<0.001		0.003	<0.001	0.57	<0.001	<0.001	0.003	<0.005					
PE164581	MDPZ7469C	26/10/2022	Hydrasleeve	35	<0.001	0.003		<0.001	0.49	<0.001	<0.001	0.003		<0.005	88	1000		
PE168204 R0	MDPZ7469C	5/05/2023	Hydrasleeve	35	<0.001	0.002		<0.001	0.53	<0.001	<0.001	0.003		0.014				
PE172208.004	MDPZ7469C	12/11/2023	Hydrasleeve	35	<0.001	0.004		<0.001	0.550	<0.001	<0.001	0.002		0.010	81			
19-12584	MDPZ7470A	25/07/2019	Airlift															
19-19463	MDPZ7470A	13/11/2019	Hydrasleeve	90														
20-08048	MDPZ7470A	2/05/2020	Hydrasleeve	90			0.003						0.03				0.2	
21-14674	MDPZ7470A	5/08/2021	Hydrasleeve	90														
PE157146	MDPZ7470A	1/12/2021	Hydrasleeve	90														
PE161850	MDPZ7470A	8/07/2022	Hydrasleeve	75	<0.002		<0.002	<0.002	1.1	<0.002	<0.002	<0.002	<0.01					
PE164581	MDPZ7470A	26/10/2022	Hydrasleeve	90											72	3800		
PE168204 R0	MDPZ7470A	5/05/2023	Hydrasleeve	90	<0.002	0.004		<0.002	1.10	<0.002	<0.002	<0.002		0.011				
PE172208.005	MDPZ7470A	12/11/2023	Hydrasleeve	90	<0.002	0.008		<0.002	1.200	<0.002	<0.002	<0.002		0.018	69			
19-12584	MDPZ7470B	25/07/2019	Airlift															
19-19463	MDPZ7470B	13/11/2019	Hydrasleeve	45														
20-08048	MDPZ7470B	2/05/2020	Hydrasleeve	45			0.003						<0.01				0.3	
21-14674	MDPZ7470B	5/08/2021	Hydrasleeve	45														
PE157146	MDPZ7470B	1/12/2021	Hydrasleeve	45														
PE161850	MDPZ7470B	8/07/2022	Hydrasleeve	35	<0.001		0.001	<0.001	0.93	<0.001	<0.001	0.006	<0.005					
PE164581	MDPZ7470B	26/10/2022	Hydrasleeve	45											110	2600		
PE168204 R0	MDPZ7470B	5/05/2023	Hydrasleeve	45	<0.001	0.005		<0.001	0.92	<0.001	<0.001	0.005		0.009				
PE172208.006	MDPZ7470B	12/11/2023	Hydrasleeve	45	<0.001	0.007		<0.001	0.920	<0.001	<0.001	0.004		0.008	100			
19-12584	MDPZ7470C	24/07/2019	Airlift															
19-19463	MDPZ7470C	13/11/2019	Hydrasleeve	20														
20-08048	MDPZ7470C	2/05/2020	Hydrasleeve	20			0.003						0.03				0.2	
21-14674	MDPZ7470C	5/08/2021	Hydrasleeve	20														
PE157146	MDPZ7470C	1/12/2021	Hydrasleeve	20														
PE161850	MDPZ7470C	8/07/2022	Hydrasleeve	90	<0.001		0.002	<0.001	0.91	0.001	<0.001	0.017	<0.005					
PE164581	MDPZ7470C	26/10/2022	Hydrasleeve	20											110	2500		
PE168204 R0	MDPZ7470C	5/05/2023	Hydrasleeve	20	<0.001	0.005		<0.001	0.87	0.001	<0.001	0.014		0.009			<0.05	
PE172208.007	MDPZ7470C	12/11/2023	Hydrasleeve	20	<0.001	0.007		<0.001	0.910	<0.001	<0.001	0.015		0.017	110		0.07	
PE172208.008	MDPZ7470C_DUP	12/11/2023	Hydrasleeve	20	<0.001	0.008		<0.001	0.830	<0.001	<0.001	0.014		0.017	110		0.10	
19-12584	MDPZ7471A	31/07/2019	Airlift															
19-19463	MDPZ7471A	13/11/2019	Hydrasleeve	72														
20-08048	MDPZ7471A	3/05/2020	Hydrasleeve	72			0.007						<0.01				<0.2	
21-14674	MDPZ7471A	5/08/2021	Hydrasleeve	72														
PE157146	MDPZ7471A	6/12/2021	Hydrasleeve	72														
PE161850	MDPZ7471A	6/07/2022	Hydrasleeve	45	<0.002		0.006	<0.002	1.5	<0.002	<0.002	0.007	<0.01					
PE164581	MDPZ7471A	19/10/2022	Hydrasleeve	72	<0.002	0.007		<0.002	1.5	0.002	<0.002	0.007		<0.01	88	3600		
PE168102 R0	MDPZ7471A	3/05/2023	Hydrasleeve	72	<0.002	0.004		<0.002	1.30	<0.002	<0.002	0.007		0.024				
PE172208.068	MDPZ7471A	12/11/2023	Hydrasleeve	72	<0.005	0.012		<0.005	1.500	<0.005	<0.005	0.006		<0.025	85			
19-12584	MDPZ7471B	31/07/2019	Airlift															
19-19463	MDPZ7471B	12/11/2019	Hydrasleeve	55														
20-08048	MDPZ7471B	3/05/2020	Hydrasleeve	55			0.007						0.04				<0.2	
21-14674	MDPZ7471B	5/08/2021	Hydrasleeve	55														
PE157146	MDPZ7471B	6/12/2021	Hydrasleeve	55														
19-12584	MDPZ7471C	31/07/2019	Airlift															
19-19463	MDPZ7471C	12/11/2019	Hydrasleeve	15														
20-08048	MDPZ7471C	3/05/2020	Hydrasleeve	15			0.006						<0.01				<0.2	
21-14674	MDPZ7471C	5/08/2021	Hydrasleeve	15														
PE157146	MDPZ7471C	6/12/2021	Hydrasleeve	15														
PE161850	MDPZ7471C	6/07/2022	Hydrasleeve	20	<0.002		0.007	<0.002	1.8	<0.002	<0.002	0.018	<0.01					
PE164581	MDPZ7471C	19/10/2022	Hydrasleeve	15	<0.002	0.009		<0.002	1.9	<0.002	<0.002	0.018		<0.01	110	3200		
PE168102 R0	MDPZ7471C	3/05/2023	Hydrasleeve	15	<0.001	0.011		<0.001	1.30	<0.001	<0.001	0.019		0.014				
PE172208.070	MDPZ7471C	12/11/2023	Hydrasleeve	15	<0.002	0.010		<0.002	1.600	<0.002	<0.002	0.018		0.015	100			
PE153340	MDPZ9201	9/07/2021	Airlift		<0.001	<0.001		<0.001	0.29	<0.001	<0.001	<0.001		0.007				
PE153340	MDPZ9202	13/07/2021	Airlift		0.005	0.002		<0.001	0.21	<0.001	<0.001	<0.001		0.04				
PE153749	MDPZ9203	31/07/2021	Airlift		0.004	0.001		<0.001	0.3	<0.001	<0.001	<0.001		0.042				

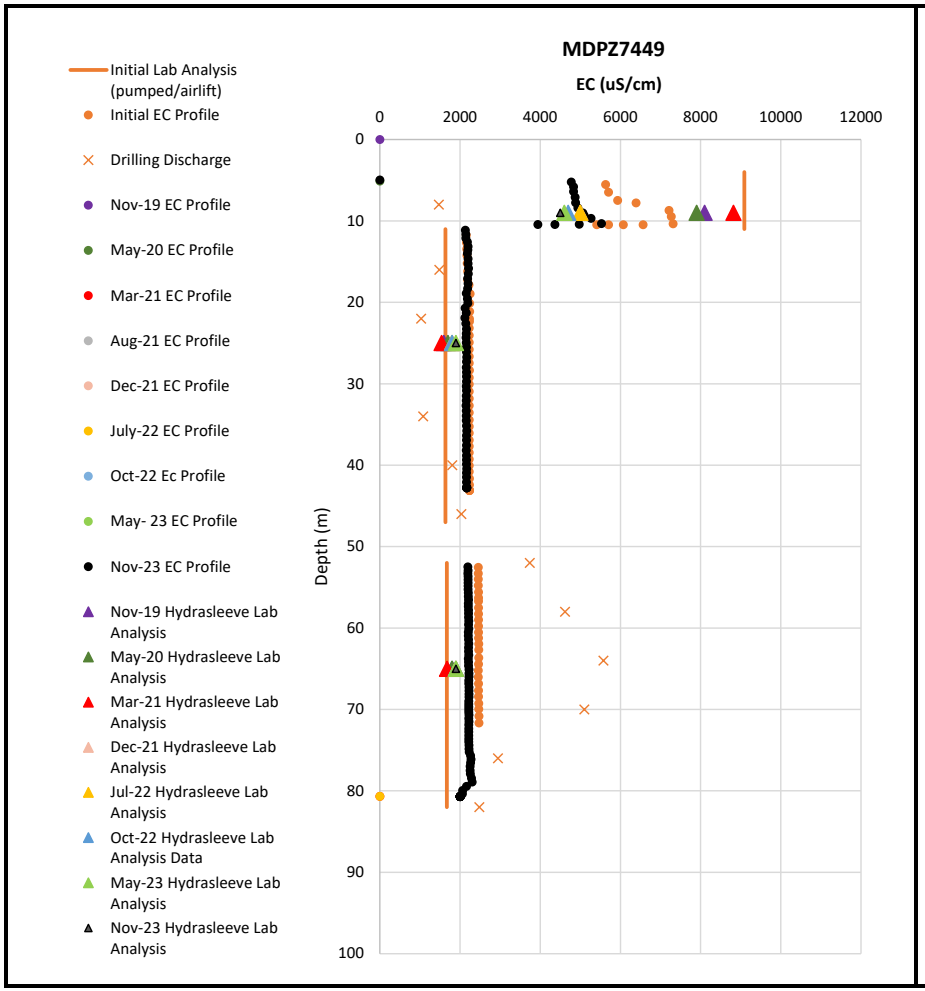
Detailed Water Quality Analysis – Groundwater

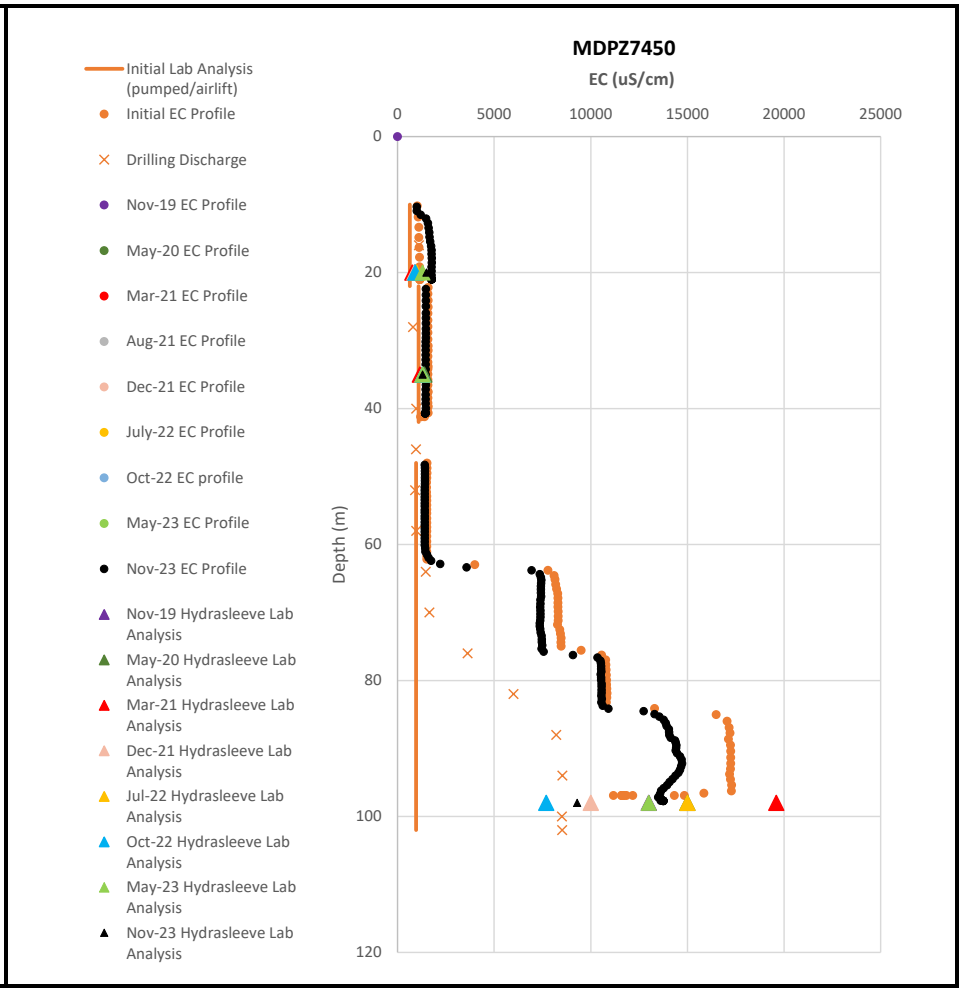
Lab Report	Bore ID	Sample Date	Sample Type	Sample Depth	Tin, Sn- Dissolved	Selenium - Dissolved	Selenium - Total	Silver, Ag- Dissolved	Strontium, Sr- Dissolved	Titanium, Ti- Dissolved	Thallium, Tl- Dissolved	Vanadium, V- Dissolved	Zinc - Total	Zinc - Dissolved	Reactive Silica as Metasilicic Acid , Si-H_2SiO3	Chloride as NaCl	Total Kjeldahl Nitrogen	Total Phosphorus
					mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
PE153634	MDPZ9204	20/07/2021	Airlift		<0.001	0.001		0.001	0.54	<0.001	<0.001	<0.001		0.018				
PE153749	MDPZ9205	24/07/2021	Airlift		0.001	0.002		<0.001	0.32	<0.001	<0.001	<0.001		0.058				
PE157321	MDPZ9205	15/12/2021	Hydrasleeve	35								<0.001	0.007					
PE161850	MDPZ9205	9/07/2022	Hydrasleeve	35	<0.001		0.001	<0.001	0.36	<0.001	<0.001	<0.001	0.007					
PE164581	MDPZ9205	26/10/2022	Hydrasleeve	35											73	670		
PE168204 R0	MDPZ9205	5/05/2023	Hydrasleeve	35	<0.001	0.001		<0.001	0.31	<0.001	<0.001	<0.001		0.023				
PE172208.016	MDPZ9205	13/11/2023	Hydrasleeve	35	<0.001	0.003		<0.001	0.310	<0.001	<0.001	<0.001		0.029	65			
PE153749	MDPZ9206	28/07/2021	Airlift		0.001	<0.001		<0.001	0.11	<0.001	<0.001	<0.001		0.41				
PE154009	MDPZ9207	3/08/2021	Airlift		<0.001	<0.001		<0.001	<0.001	<0.001	0.13	<0.001		0.18				
PE154009	MDPZ9208	7/08/2021	Airlift		<0.001	0.001		<0.001	<0.001	<0.001	0.27	<0.001		0.005				
PE154009	MDPZ9209	11/08/2021	Airlift		<0.001	0.002		<0.001	<0.001	<0.001	0.15	<0.001		0.009				
PE154235	MDPZ9210	15/08/2021	Airlift		<0.001	<0.0001		0.001	0.57	<0.001	<0.001	<0.001		0.094				
PE155073	MDPZ9211	17/09/2021	Airlift		<0.005	0.008		<0.005	2.5	<0.005	<0.005	<0.005		<0.025				
PE157321	MDPZ9211	16/12/2021	Hydrasleeve	48								<0.005	<0.025					
PE161850	MDPZ9211	7/07/2022	Hydrasleeve	48	<0.002		0.009	<0.002	1.7	0.003	<0.002	0.003	<0.01					
PE164581	MDPZ9211	23/10/2022	Hydrasleeve	48	<0.005	0.009		<0.005	1.7	<0.005	<0.005	<0.005		<0.025	69	4800		
PE168204 R0	MDPZ9211	4/05/2023	Hydrasleeve	48	<0.005	0.020		<0.005	1.60	<0.005	<0.005	<0.005		<0.025				
PE172208.056	MDPZ9211	12/11/2023	Hydrasleeve	48	<0.005	0.016		<0.005	1.900	<0.005	<0.005	<0.005		<0.025	66			
PE155073	MDPZ9212	24/09/2021	Airlift		<0.005	0.01		<0.005	3.1	<0.005	<0.005	<0.005		<0.025				
PE157321	MDPZ9212D	16/12/2021	Hydrasleeve	105								<0.005	0.035					
PE161850	MDPZ9212D	7/07/2022	Hydrasleeve	105	<0.005		0.016	<0.005	3.4	<0.005	<0.005	<0.005	<0.025					
PE164581	MDPZ9212D	23/10/2022	Hydrasleeve	105	<0.005	0.007		<0.005	3.3	<0.005	<0.005	<0.005		<0.025	52	7600		
PE168204 R0	MDPZ9212D	4/05/2023	Hydrasleeve	105	<0.005	0.018		<0.005	3.40	<0.005	<0.005	<0.005		<0.025				
PE172208.055	MDPZ9212D	12/11/2023	Hydrasleeve	105	<0.005	0.011		<0.005	3.600	<0.005	<0.005	<0.005		0.240	49			
PE157321	MDPZ9212S	16/12/2021	Hydrasleeve	20								0.025	<0.025					
PE161850	MDPZ9212S	7/07/2022	Hydrasleeve	20	<0.005		<0.005	<0.005	2.6	<0.005	<0.005	0.035	<0.025					
PE164581	MDPZ9212S	23/10/2022	Hydrasleeve	20	<0.005	0.014		<0.005	2.5	0.006	<0.005	0.025		<0.025	110	6800		
PE168204 R0	MDPZ9212S	4/05/2023	Hydrasleeve	20	<0.005	<0.005		<0.005	2.50	<0.005	<0.005	0.024		<0.025				
PE172208.054	MDPZ9212S	12/11/2023	Hydrasleeve	20	<0.005	0.022		<0.005	2.600	<0.005	<0.005	0.022		<0.025	100			
PE155297	MDPZ9213	1/10/2021	Airlift		<0.001	0.003		<0.001	0.45	<0.001	<0.001	0.002		0.006				
PE157321	MDPZ9213	13/12/2021	Hydrasleeve	40								0.002	0.008					
PE161850	MDPZ9213	6/07/2022	Hydrasleeve	40	<0.001		0.004	<0.001	0.38	<0.001	<0.001	0.002	<0.005					
PE164581	MDPZ9213	19/10/2022	Hydrasleeve	40	<0.001	0.003		<0.001	0.41	<0.001	<0.001	0.001		<0.005	87	520		
PE168102 R0	MDPZ9213	3/05/2023	Hydrasleeve	40	<0.001	0.005		<0.001	0.35	<0.001	<0.001	0.002		0.018				
PE172208.071	MDPZ9213	13/11/2023	Hydrasleeve	40	<0.001	0.005		<0.001	0.380	<0.001	<0.001	0.002		0.180	83			
PE155569	MDPZ9214	10/10/2021	Airlift		<0.001	0.005		0.003	0.9	<0.001	<0.001	0.006		0.019				
PE157321	MDPZ9214	15/12/2021	Hydrasleeve	40								0.007	<0.005					
PE161850	MDPZ9214	6/07/2022	Hydrasleeve	40	<0.001		0.004	<0.001	0.66	<0.001	<0.001	0.008	<0.005					
PE164581	MDPZ9214	19/10/2022	Hydrasleeve	40	<0.001	0.003		<0.001	0.68	0.001	<0.001	0.007		<0.005	110	1700		
PE168102 R0	MDPZ9214	3/05/2023	Hydrasleeve	40	<0.001	0.004		<0.001	0.64	<0.001	<0.001	0.006		0.017				
PE172208.072	MDPZ9214	13/11/2023	Hydrasleeve	40	<0.001	0.005		<0.001	0.770	0.001	0.001	0.012		0.026	110			
PE155734	MDPZ9215D	8/10/2021	Airlift		<0.005	0.007		0.006	4.3	<0.005	<0.005	<0.005		<0.025				
PE157321	MDPZ9215D	15/12/2021	Hydrasleeve	80								<0.005	0.047					
PE161850	MDPZ9215D	6/07/2022	Hydrasleeve	80	<0.002		0.01	0.003	1.3	<0.002	<0.002	0.003	0.025					
PE164581	MDPZ9215D	19/10/2022	Hydrasleeve	80	<0.001	0.006		0.002	1.1	<0.001	<0.001	0.003		0.01	78	2800		
PE168102 R0	MDPZ9215D	3/05/2023	Hydrasleeve	80	<0.001	0.002		<0.001	1.00	<0.001	<0.001	0.002		0.018				
PE172208.073	MDPZ9215D	12/11/2023	Hydrasleeve	80	<0.005	0.008		<0.005	1.500	<0.005	<0.005	<0.005		<0.025	68			
PE155887	MDPZ9215S	27/10/2021	Airlift		<0.001	0.005		<0.001	0.73	<0.001	<0.001	0.008		0.054				
PE157321	MDPZ9215S	15/12/2021	Hydrasleeve	20								0.004	0.006					
PE161850	MDPZ9215S	6/07/2022	Hydrasleeve	20	<0.001		0.007	0.002	0.88	<0.001	<0.001	0.005	0.007					
PE164581	MDPZ9215S	19/10/2022	Hydrasleeve	20	<0.001	0.006		0.002	0.88	<0.001	<0.001	0.005		<0.005	73	2100		
PE168102 R0	MDPZ9215S	3/05/2023	Hydrasleeve	20	<0.001	0.006		<0.001	0.81	<0.001	<0.001	0.004		0.015			<0.05	0.03
PE172208.042	MDPZ9215S	12/11/2023	Hydrasleeve	20	<0.001	0.006		<0.001	0.670	<0.001	<0.001	0.037		0.016	81			
PE155887	MDPZ9216	24/10/2021	Airlift		<0.005	0.006		<0.005	4.7	<0.005	<0.005	<0.005		0.064				
PE157321	MDPZ9216	15/12/2021	Hydrasleeve	90								<0.005	0.043					
PE161850	MDPZ9216	6/07/2022	Hydrasleeve	90	<0.005		<0.005	<0.005	4.3	0.005	<0.005	<0.005	<0.025					
PE164581	MDPZ9216	19/10/2022	Hydrasleeve	90	<0.005	<0.005		0.005	4.4	<0.005	<0.005	<0.005		<0.025	36	9200		
PE168102 R0	MDPZ9216	3/05/2023	Hydrasleeve	90	<0.005	<0.005		<0.005	4.20	<0.005	<0.005	<0.005		<0.025				
PE172208.074	MDPZ9216	14/11/2023	Hydrasleeve	90	<0.005	0.007		<0.005	4.400	<0.005	<0.005	<0.005		<0.025	32			
PE156870	MDPZ9217	20/11/2021	Airlift		<0.005	0.007		<0.005	2.3	<0.005	<0.005	<0.005		<0.025				
PE157321	MDPZ9217	13/12/2021	Hydrasleeve	30								<0.002	<0.01					
PE161850	MDPZ9217	5/07/2022	Hydrasleeve	30	<0.001		0.003	0.001	1.7	0.001	<0.001	<0.001	<0.005					
PE164581	MDPZ9217	23/10/2022	Hydrasleeve	30	<0.001	0.006		0.001	1.8	<0.001	<0.001	<0.001		<0.005	53	2300		
PE168102 R0	MDPZ9217	3/05/2023	Hydrasleeve	30	<0.001	0.005		<0.001	1.60	<0.001	<0.001	<0.001		0.015				
PE172208.043	MDPZ9217	10/11/2023	Hydrasleeve	30	<0.002	0.120		<0.002	1.800	0.003	<0.002	<0.002		0.031	59		0.18	
PE156870	MDPZ9218	26/11/2021	Airlift		<0.002	<0.002		<0.002	1.7	<0.002	<0.002	<0.002		<0.01				
PE157321	MDPZ9218	13/12/2021	Hydrasleeve	30								<0.002	<0.01					
PE161850	MDPZ9218	5/07/2022	Hydrasleeve	30	<0.001		<0.001	0.002	0.84	<0.001	<0.001	0.001	<0.005					
PE164581	MDPZ9218	23/10/2022	Hydrasleeve	30	<0.001	0.002		0.001	0.81	0.001	<0.001	0.001		<0.005	66	1500		
PE168102 R0	MDPZ9218	2/05/2023	Hydrasleeve	30	<0.001	<0.001		<0.001	0.85	<0.001	<0.001	0.001		0.015				
PE172208.044	MDPZ9218	11/11/2023	Hydrasleeve	30	<0.001	0.004		<0.001	1.2	<0.001	<0.001	<0.001		0.020	48		3.7	
PE172208.075	MDPZ9218	10/11/2023	Hydrasleeve	30	<0.001	0.003		<0.001	1.200	0.001	<0.001	0.002		0.010	50		1.1	
PE157040	MDPZ9219	30/11/2021	Airlift		<0.001	0.002		0.006	0.6	<0.001	<0.001	0.001		<0.005				
PE157321	MDPZ9219	13/12/2021	Hydrasleeve	30								0.002	<0.005					
PE161850	MDPZ9219	5/07/2022	Hydrasleeve	30	<0.001		0.001	0.001	1.1	0.001	<0.001	0.003	<0.005					
PE164581	MDPZ9219	24/10/2022	Hydrasleeve	30	<0.001	0.003		<0.001	0.73	<0.001	<0.001	0.002		<0.005	77	1500		
PE168102 R0	MDPZ9219	2/05/2023	Hydrasleeve	30	<0.001	0.001		<0.001	0.64	<0.001	<0.001	0.002		0.017			<0.05	<0.02
PE172208.045	MDPZ9219	9/11/2023	Hydrasleeve	30	<0.001	0.004		<0.001	0.690	<0.001	<0.001	0.002		0.017	69		0.07	
PE172208.048	MDPZ9219	9/11/2023	Hydrasleeve	30	<0.001	0.004		<0.001	0.700	<0.001	<0.001	0.002		0.006	69		0.12	
PE157040	MDPZ9220	6/12/2021	Airlift		<0.001	<0.001		0.002	0.46	<0.001	<0.001	<0.001		0.007				
PE157321	MDPZ9220	13/12/2021	Hydrasleeve	30								<0.001	<0.005					
PE161850	MDPZ9220	5/07/2022	Hydrasleeve	30	<0.001		<0.001	0.002	0.42	<0.001	<0.001	<0.001	<0.005					
PE164581	MDPZ9220	24/10/2022	Hydrasleeve	30	<0.001	<0.001		<0.001	0.43	<0.001	<0.001	<0.001		<0.005	29	870		
PE168102 R0	MDPZ9220	2/05/2023	Hydrasleeve	30	<0.001	<0.001		<0.001	0.41	<0.001	<0.001	<0.001		0.018				
PE172208.046	MDPZ9220	9/11/2023	Hydrasleeve	30	<0.001	0.001		<0.001	0.470	<0.001	<0.001	<0.001		<0.005	40		0.10	
PE157322	MDPZ9221	12/12/2021	Airlift		<0.001	0.002		<0.001	0.73	<0.001	<0.001	0.002		<0.005				
PE157321	MDPZ9221	14/12/2021	Hydrasleeve	30								0.003	<0.005					
PE161850	MDPZ9221	5/07/2022	Hydrasleeve	30	<0.001		0.001	0.003	0.77	<0.001	<0.001	0.003	0.006					

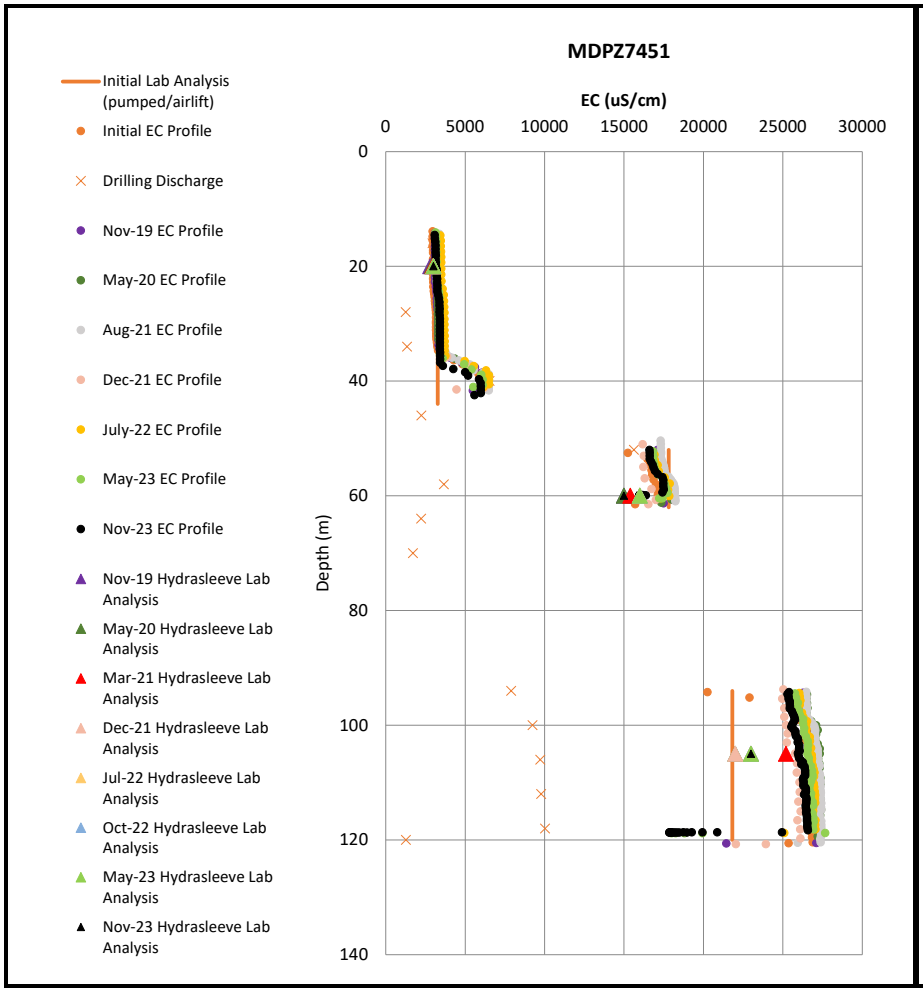
Detailed Water Quality Analysis – Groundwater

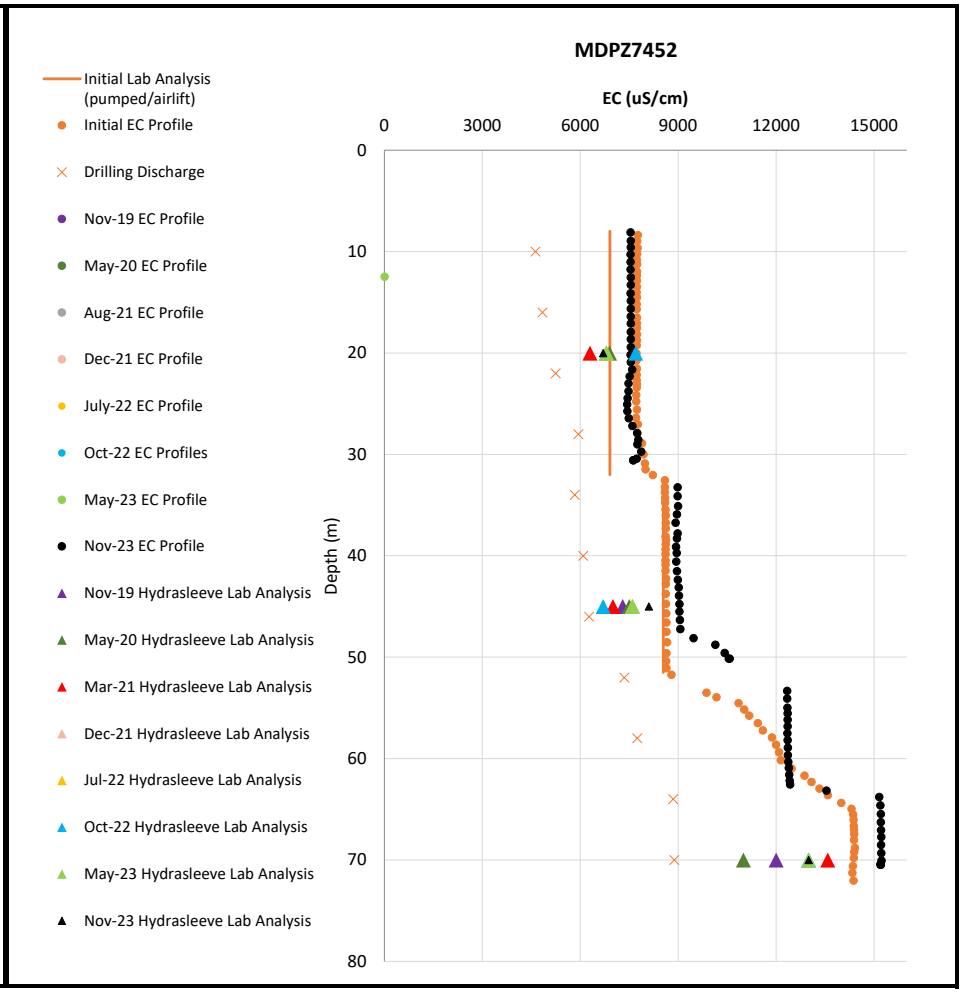
Lab Report	Bore ID	Sample Date	Sample Type	Sample Depth	Tin, Sn- Dissolved	Selenium - Dissolved	Selenium - Total	Silver, Ag- Dissolved	Strontium, Sr- Dissolved	Titanium, Ti- Dissolved	Thallium, Tl- Dissolved	Vanadium, V- Dissolved	Zinc - Total	Zinc - Dissolved	Reactive Silica as Metasilicic Acid , Si- H_2SiO3	Chloride as NaCl	Total Kjeldahl Nitrogen	Total Phosphorus
					mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
PE164581	MDPZ9221	24/10/2022	Hydrasleeve	30	<0.001	0.002		<0.001	0.77	<0.001	<0.001	0.003		<0.005	90	1300		
PE168102 R0	MDPZ9221	2/05/2023	Hydrasleeve	30	<0.001	0.002		<0.001	0.68	<0.001	<0.001	0.003		0.020				
PE172208.047	MDPZ9221	9/11/2023	Hydrasleeve	30	<0.001	0.005		<0.001	0.770	<0.001	<0.001	0.003		<0.005	83		0.14	
PE172300	MDPZ9222S	21/10/2023	Hydrasleeve	37										0.012		1600		
PE172300	MDPZ9223S	21/10/2023	Hydrasleeve	28										<0.005		1000		
PE172300	MDPZ9224D	30/10/2023	Airlift	Airlift										<0.010		3800		
PE172300	MDPZ9224S	30/10/2023	Airlift	Airlift										<0.005		1600		
PE172300	MDPZ922S	5/11/2023	Airlift	Airlift										<0.005		710		

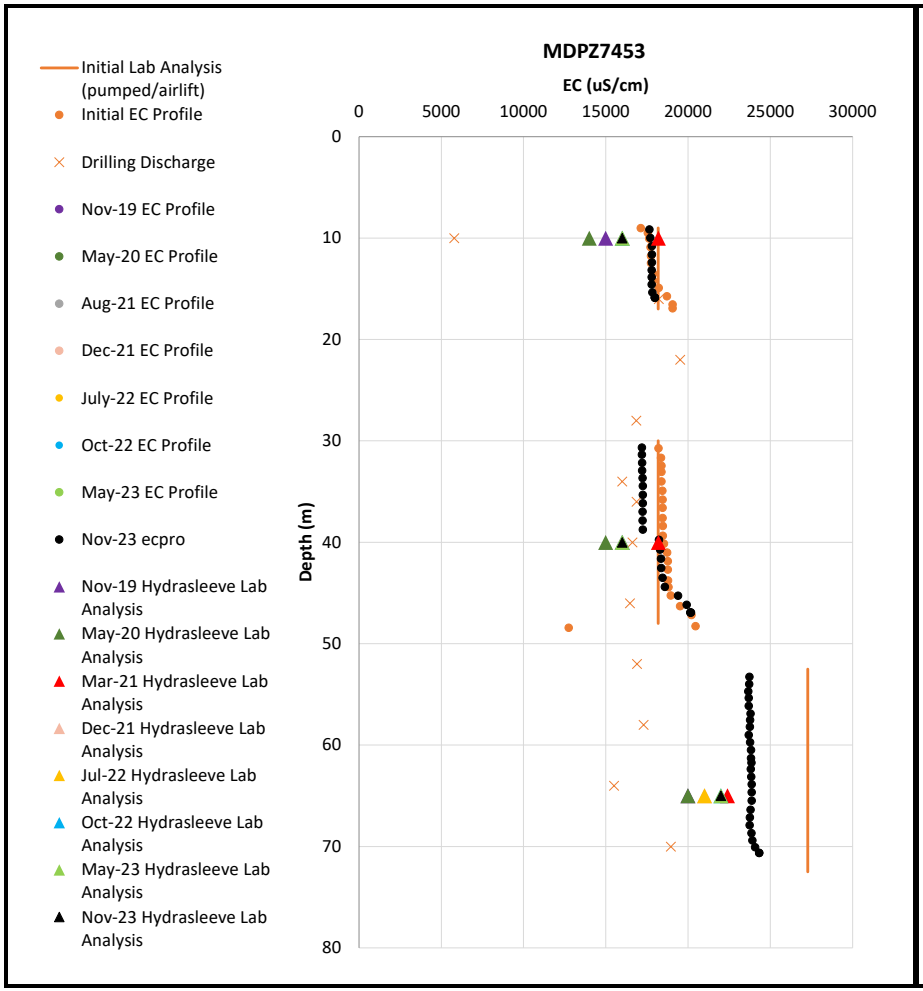
APPENDIX H
SALINITY PROFILE PLOTS

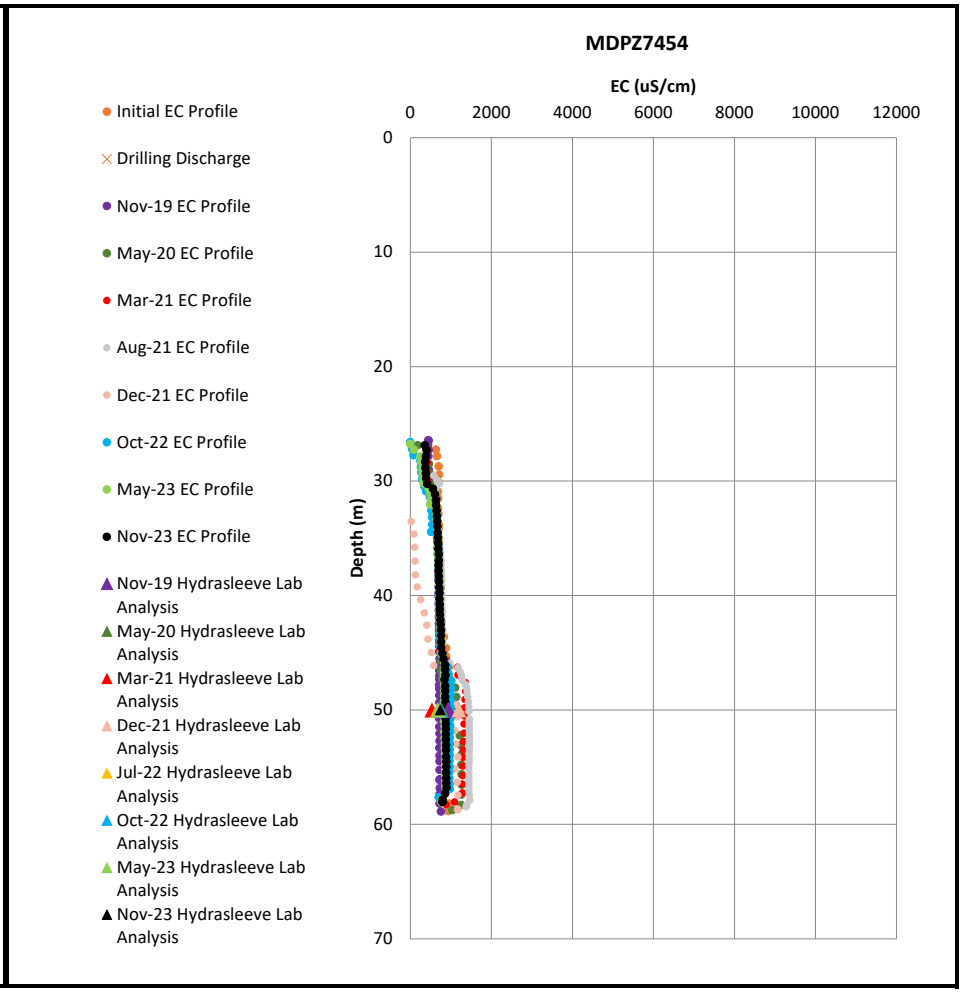

MDPZ7449
EC (uS/cm)
0
2000
4000
6000
8000
10000
12000
Depth (m)
0
10
20
30
40
50
60
70
80
90
100
Initial Lab Analysis (pumped/airlift)
Initial EC Profile
Drilling Discharge
Nov-19 EC Profile
May-20 EC Profile
Mar-21 EC Profile
Aug-21 EC Profile
Dec-21 EC Profile
July-22 EC Profile
Oct-22 Ec Profile
May- 23 EC Profile
Nov-23 EC Profile
Nov-19 Hydrasleeve Lab Analysis
May-20 Hydrasleeve Lab Analysis
Mar-21 Hydrasleeve Lab Analysis
Dec-21 Hydrasleeve Lab Analysis
Jul-22 Hydrasleeve Lab Analysis
Oct-22 Hydrasleeve Lab Analysis Data
May-23 Hydrasleeve Lab Analysis
Nov-23 Hydrasleeve Lab Analysis

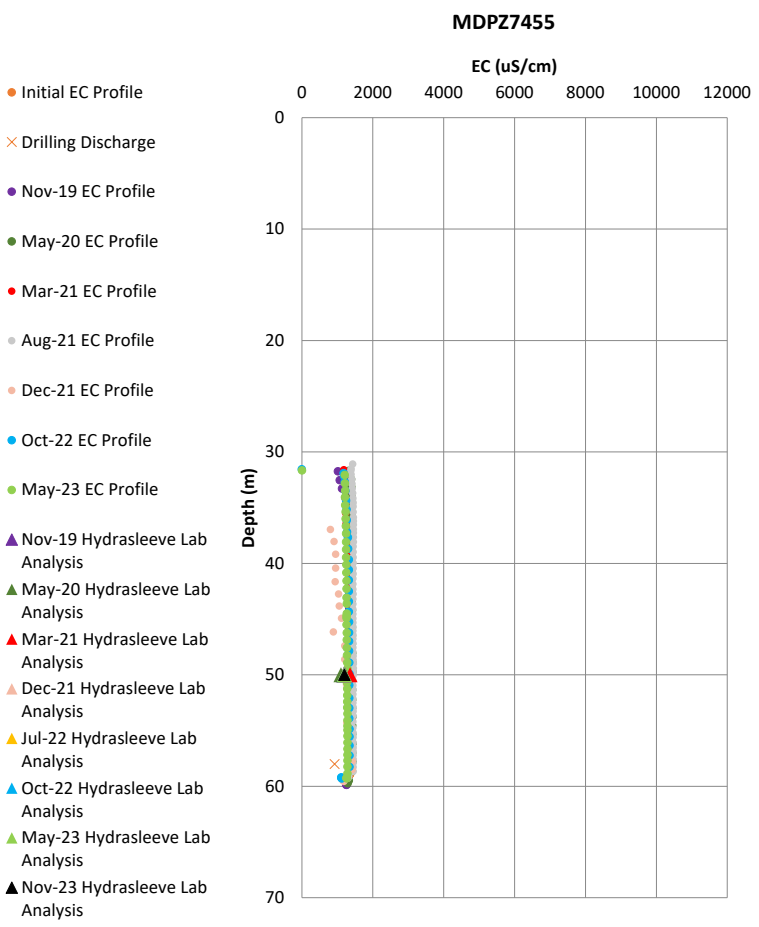

MDPZ7450
EC (uS/cm)
0
5000
10000
15000
20000
25000
Depth (m)
0
20
40
60
80
100
120
Initial Lab Analysis (pumped/airlift)
Initial EC Profile
Drilling Discharge
Nov-19 EC Profile
May-20 EC Profile
Mar-21 EC Profile
Aug-21 EC Profile
Dec-21 EC Profile
July-22 EC Profile
Oct-22 EC profile
May-23 EC Profile
Nov-23 EC Profile
Nov-19 Hydrasleeve Lab Analysis
May-20 Hydrasleeve Lab Analysis
Mar-21 Hydrasleeve Lab Analysis
Dec-21 Hydrasleeve Lab Analysis
Jul-22 Hydrasleeve Lab Analysis
Oct-22 Hydrasleeve Lab Analysis
May-23 Hydrasleeve Lab Analysis
Nov-23 Hydrasleeve Lab Analysis


MDPZ7451
EC (uS/cm)
0
5000
10000
15000
20000
25000
30000
Depth (m)
0
20
40
60
80
100
120
140
Initial Lab Analysis (pumped/airlift)
Initial EC Profile
Drilling Discharge
Nov-19 EC Profile
May-20 EC Profile
Aug-21 EC Profile
Dec-21 EC Profile
July-22 EC Profile
May-23 EC Profile
Nov-23 EC Profile
Nov-19 Hydrasleeve Lab Analysis
May-20 Hydrasleeve Lab Analysis
Mar-21 Hydrasleeve Lab Analysis
Dec-21 Hydrasleeve Lab Analysis
Jul-22 Hydrasleeve Lab Analysis
Oct-22 Hydrasleeve Lab Analysis
May-23 Hydrasleeve Lab Analysis
Nov-23 Hydrasleeve Lab Analysis

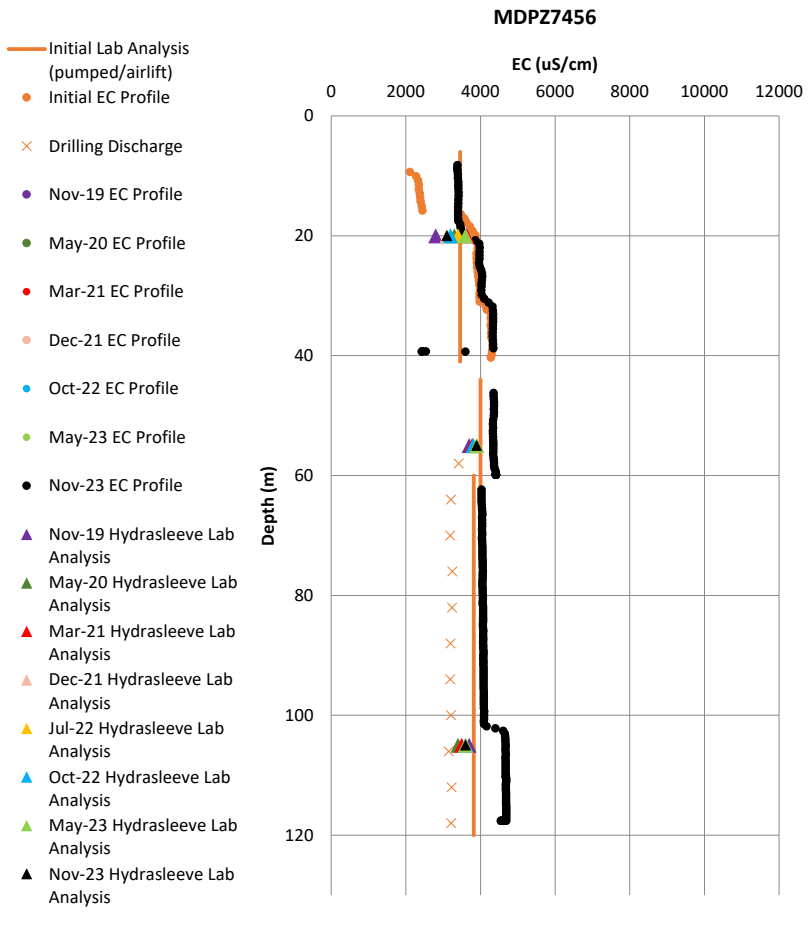

MDPZ7452
EC (uS/cm)
0
3000
6000
9000
12000
15000
Depth (m)
0
10
20
30
40
50
60
70
80
Initial Lab Analysis (pumped/airlift)
Initial EC Profile
Drilling Discharge
Nov-19 EC Profile
May-20 EC Profile
Aug-21 EC Profile
Dec-21 EC Profile
July-22 EC Profile
Oct-22 EC Profiles
May-23 EC Profile
Nov-23 EC Profile
Nov-19 Hydrasleeve Lab Analysis
May-20 Hydrasleeve Lab Analysis
Mar-21 Hydrasleeve Lab Analysis
Dec-21 Hydrasleeve Lab Analysis
Jul-22 Hydrasleeve Lab Analysis
Oct-22 Hydrasleeve Lab Analysis
May-23 Hydrasleeve Lab Analysis
Nov-23 Hydrasleeve Lab Analysis

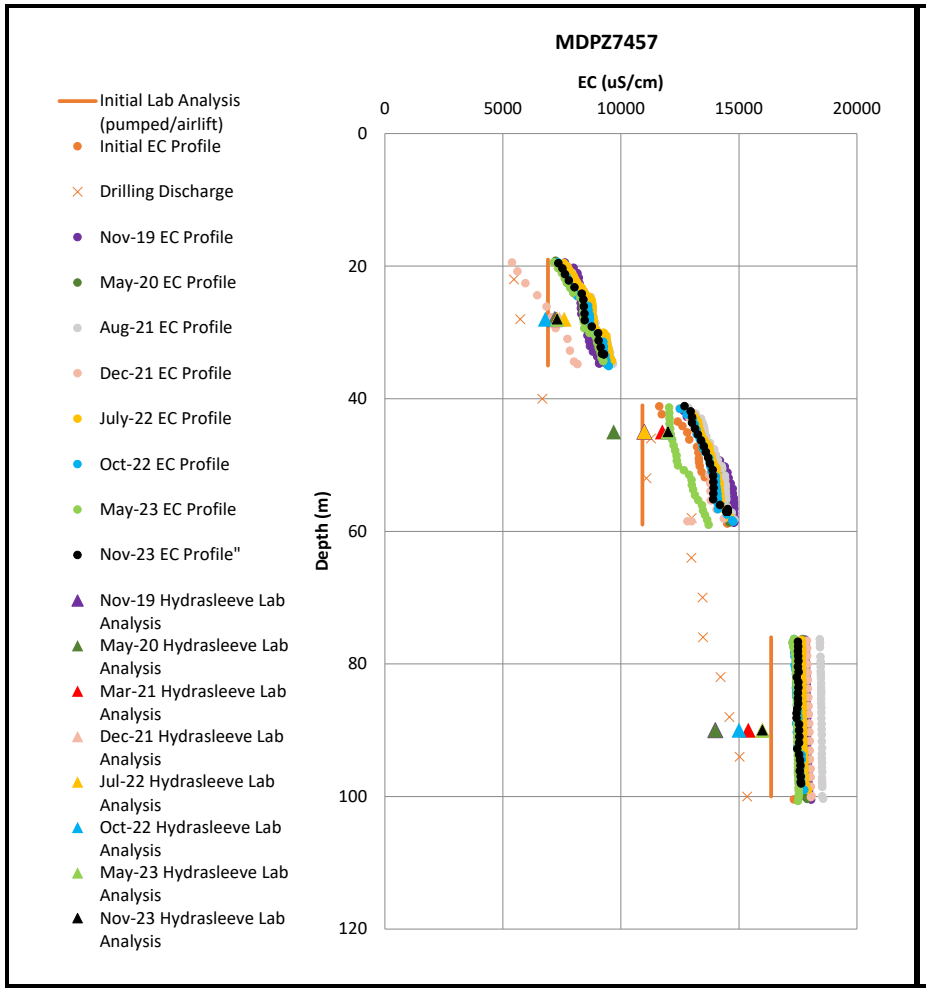

MDPZ7453
EC (uS/cm)
0
5000
10000
15000
20000
25000
30000
Depth (m)
0
10
20
30
40
50
60
70
80
Initial Lab Analysis (pumped/airlift)
Initial EC Profile
Drilling Discharge
Nov-19 EC Profile
May-20 EC Profile
Aug-21 EC Profile
Dec-21 EC Profile
July-22 EC Profile
Oct-22 EC Profile
May-23 EC Profile
Nov-23 ecpro
Nov-19 Hydrasleeve Lab Analysis
May-20 Hydrasleeve Lab Analysis
Mar-21 Hydrasleeve Lab Analysis
Dec-21 Hydrasleeve Lab Analysis
Jul-22 Hydrasleeve Lab Analysis
Oct-22 Hydrasleeve Lab Analysis
May-23 Hydrasleeve Lab Analysis
Nov-23 Hydrasleeve Lab Analysis

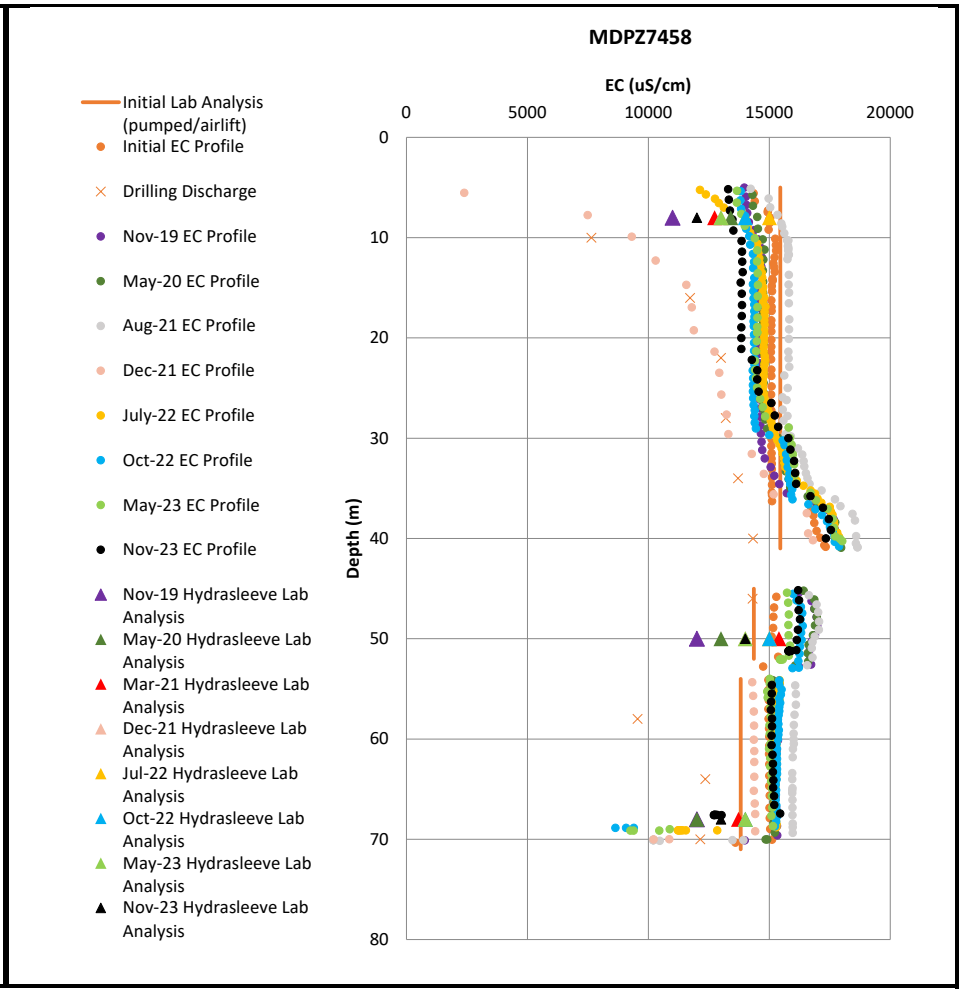

MDPZ7454
EC (uS/cm)
0
2000
4000
6000
8000
10000
12000
Depth (m)
0
10
20
30
40
50
60
70
Initial EC Profile
Drilling Discharge
Nov-19 EC Profile
May-20 EC Profile
Mar-21 EC Profile
Aug-21 EC Profile
Dec-21 EC Profile
Oct-22 EC Profile
May-23 EC Profile
Nov-23 EC Profile
Nov-19 Hydrasleeve Lab Analysis
May-20 Hydrasleeve Lab Analysis
Mar-21 Hydrasleeve Lab Analysis
Dec-21 Hydrasleeve Lab Analysis
Jul-22 Hydrasleeve Lab Analysis
Oct-22 Hydrasleeve Lab Analysis
May-23 Hydrasleeve Lab Analysis
Nov-23 Hydrasleeve Lab Analysis



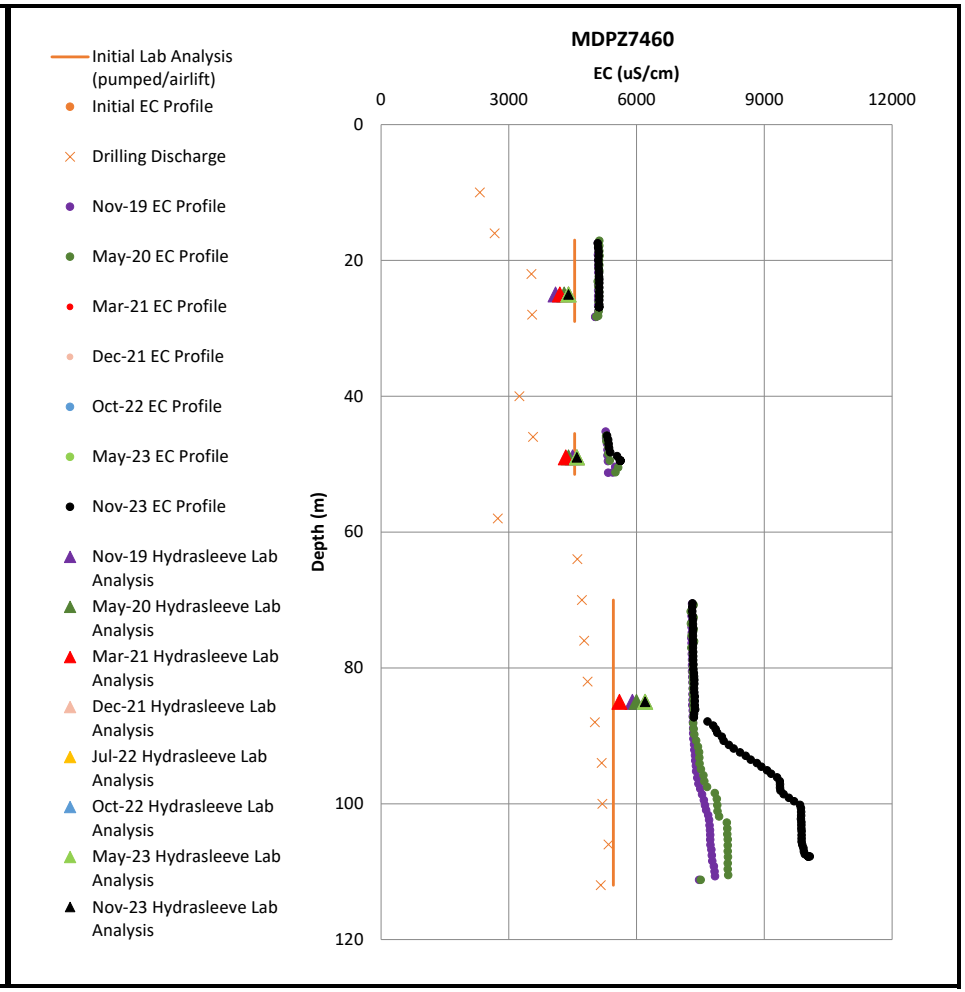
Limited drilling discharge data as discharge was too muddy (insufficient yield)

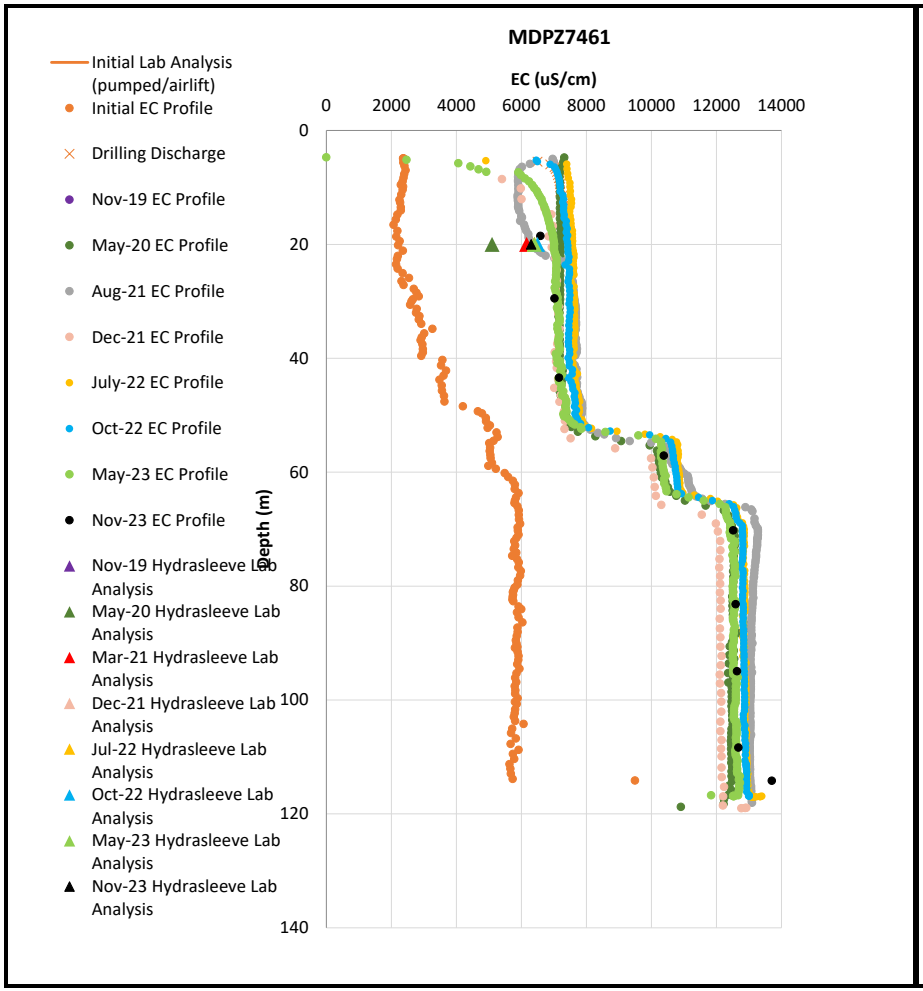


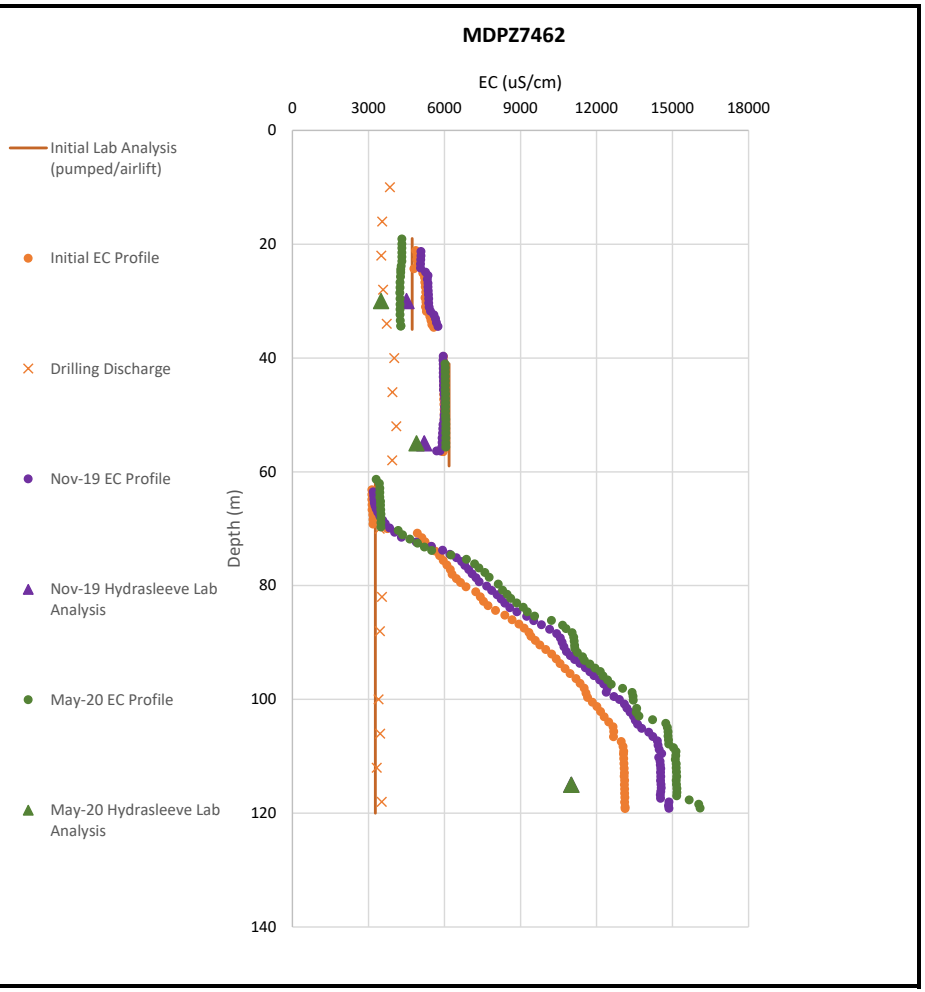

MDPZ7457
EC (uS/cm)
0
5000
10000
15000
20000
Depth (m)
0
20
40
60
80
100
120
Initial Lab Analysis (pumped/airlift)
Initial EC Profile
Drilling Discharge
Nov-19 EC Profile
May-20 EC Profile
Aug-21 EC Profile
Dec-21 EC Profile
July-22 EC Profile
Oct-22 EC Profile
May-23 EC Profile
Nov-23 EC Profile"
Nov-19 Hydrasleeve Lab Analysis
May-20 Hydrasleeve Lab Analysis
Mar-21 Hydrasleeve Lab Analysis
Dec-21 Hydrasleeve Lab Analysis
Jul-22 Hydrasleeve Lab Analysis
Oct-22 Hydrasleeve Lab Analysis
May-23 Hydrasleeve Lab Analysis
Nov-23 Hydrasleeve Lab Analysis

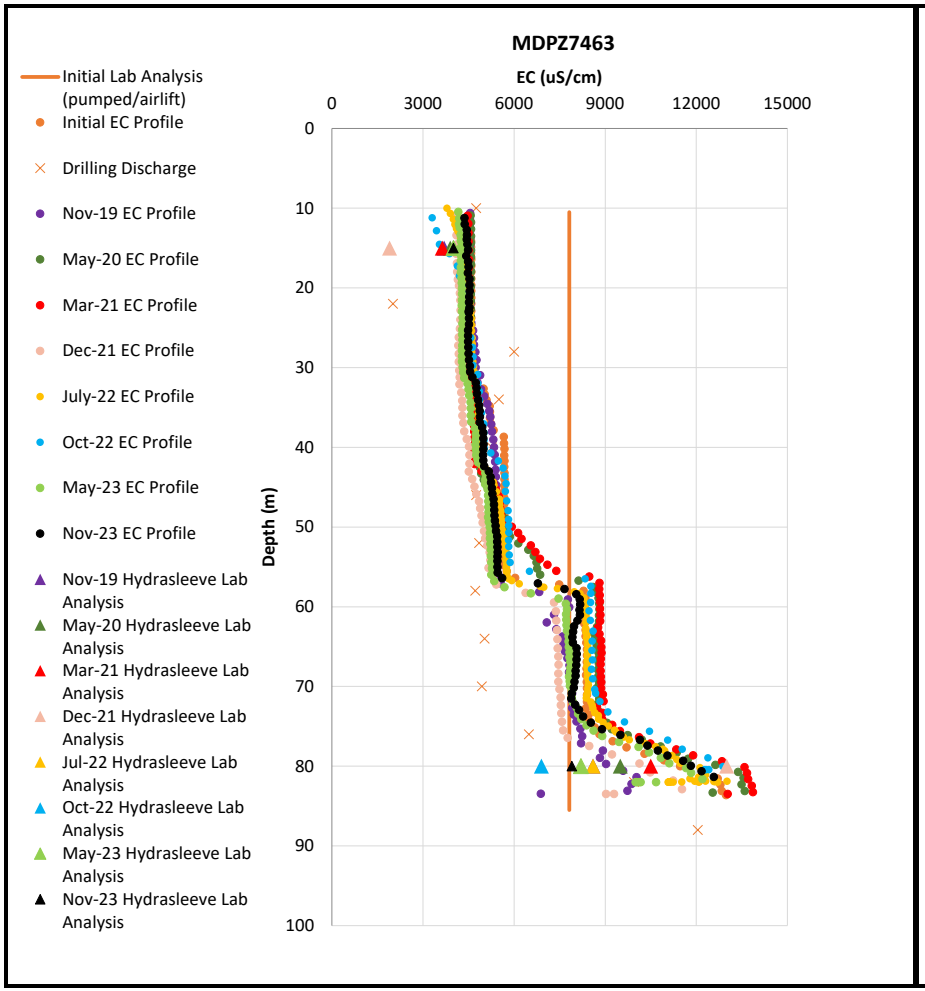

MDPZ7458
EC (uS/cm)
0
5000
10000
15000
20000
Depth (m)
0
10
20
30
40
50
60
70
80
Initial Lab Analysis (pumped/airlift)
Initial EC Profile
Drilling Discharge
Nov-19 EC Profile
May-20 EC Profile
Aug-21 EC Profile
Dec-21 EC Profile
July-22 EC Profile
Oct-22 EC Profile
May-23 EC Profile
Nov-23 EC Profile
Nov-19 Hydrasleeve Lab Analysis
May-20 Hydrasleeve Lab Analysis
Mar-21 Hydrasleeve Lab Analysis
Dec-21 Hydrasleeve Lab Analysis
Jul-22 Hydrasleeve Lab Analysis
Oct-22 Hydrasleeve Lab Analysis
May-23 Hydrasleeve Lab Analysis
Nov-23 Hydrasleeve Lab Analysis

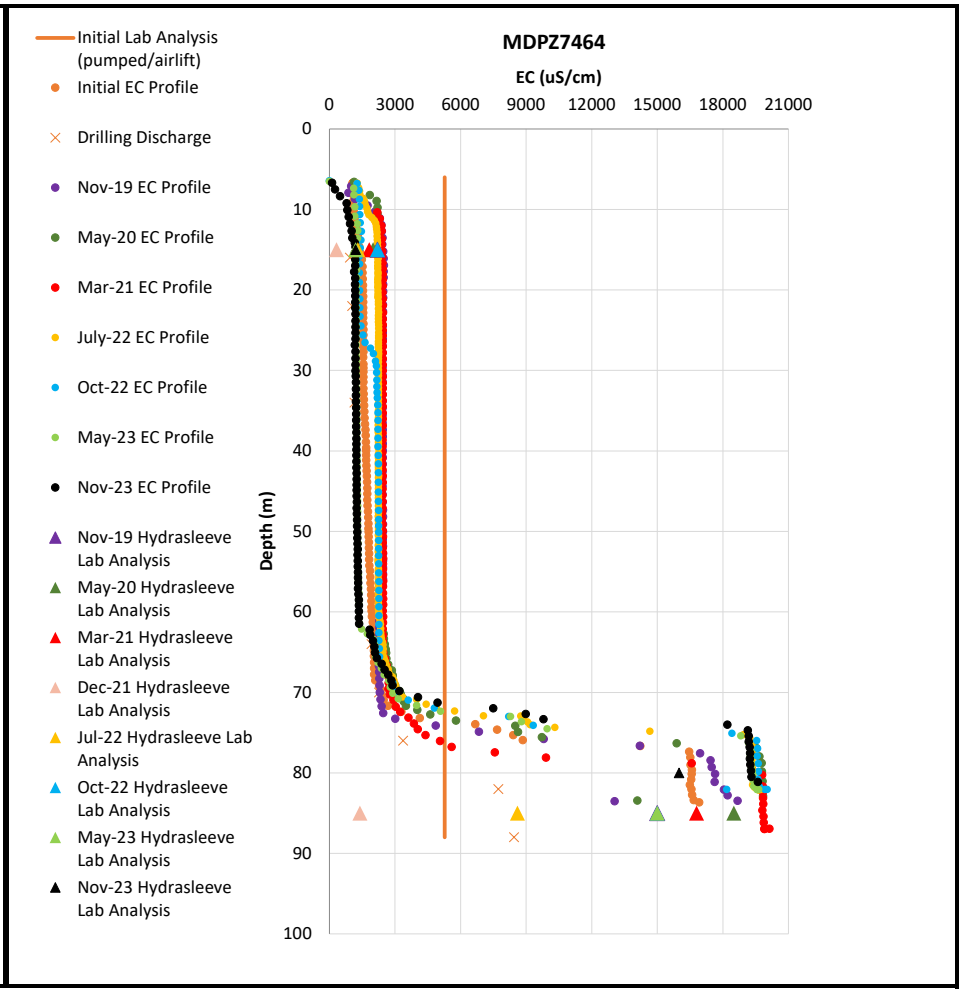

MDPZ7459
EC (uS/cm)
0
5000
10000
15000
20000
Depth (m)
0
5
10
15
20
25
30
Initial Lab Analysis (pumped/airlift)
Initial EC Profile
Drilling Discharge
Nov-19 EC Profile
May-20 EC Profile
Mar-21 EC Profile
Dec-21 EC Profile
July-22 EC Profile
Oct-22 EC Profile
May-23 EC Profile
Nov-23 EC Profile
Nov-19 Hydrasleeve Lab Analysis
May-20 Hydrasleeve Lab Analysis
Mar-21 Hydrasleeve Lab Analysis
Dec-21 Hydrasleeve Lab Analysis
Jul-22 Hydrasleeve Lab Analysis
Oct-22 Hydrasleeve Lab Analysis
May-23 Hydrasleeve Lab Analysis
Nov-23 Hydrasleeve Lab Analysis

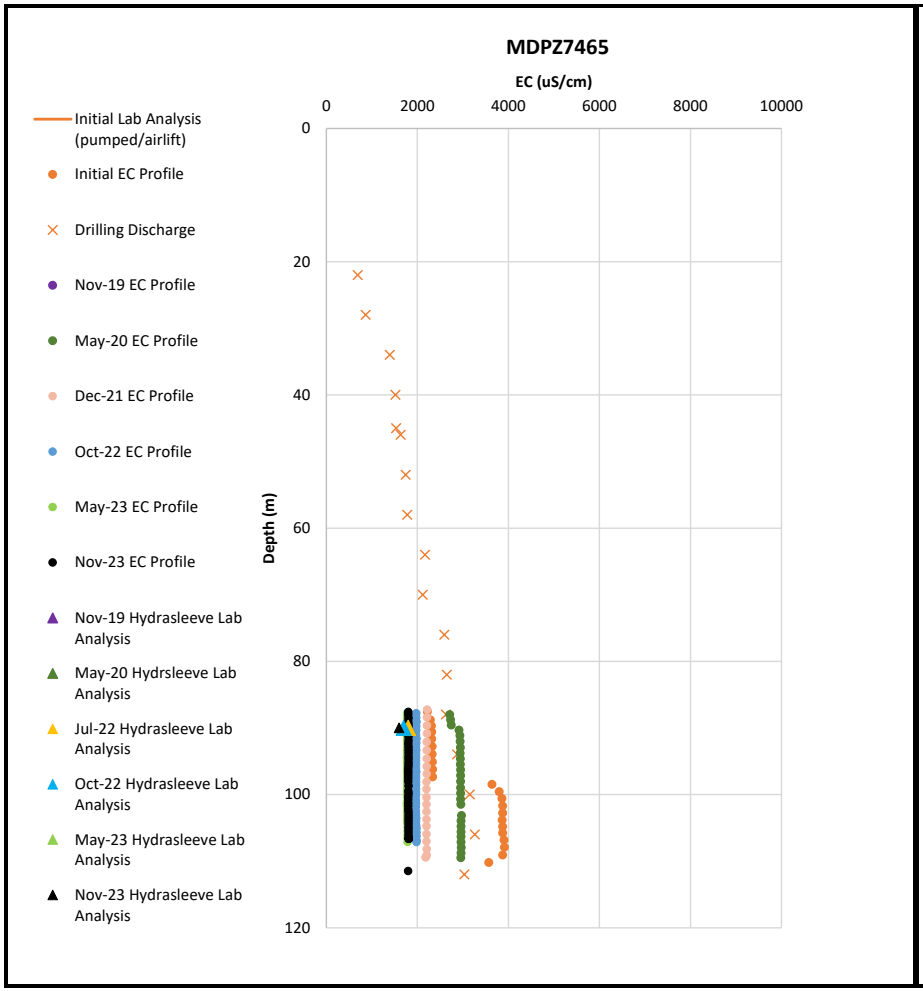

MDPZ7460
EC (uS/cm)
0
3000
6000
9000
12000
Depth (m)
0
20
40
60
80
100
120
Initial Lab Analysis (pumped/airlift)
Initial EC Profile
Drilling Discharge
Nov-19 EC Profile
May-20 EC Profile
Mar-21 EC Profile
Dec-21 EC Profile
Oct-22 EC Profile
May-23 EC Profile
Nov-23 EC Profile
Nov-19 Hydrasleeve Lab Analysis
May-20 Hydrasleeve Lab Analysis
Mar-21 Hydrasleeve Lab Analysis
Dec-21 Hydrasleeve Lab Analysis
Jul-22 Hydrasleeve Lab Analysis
Oct-22 Hydrasleeve Lab Analysis
May-23 Hydrasleeve Lab Analysis
Nov-23 Hydrasleeve Lab Analysis

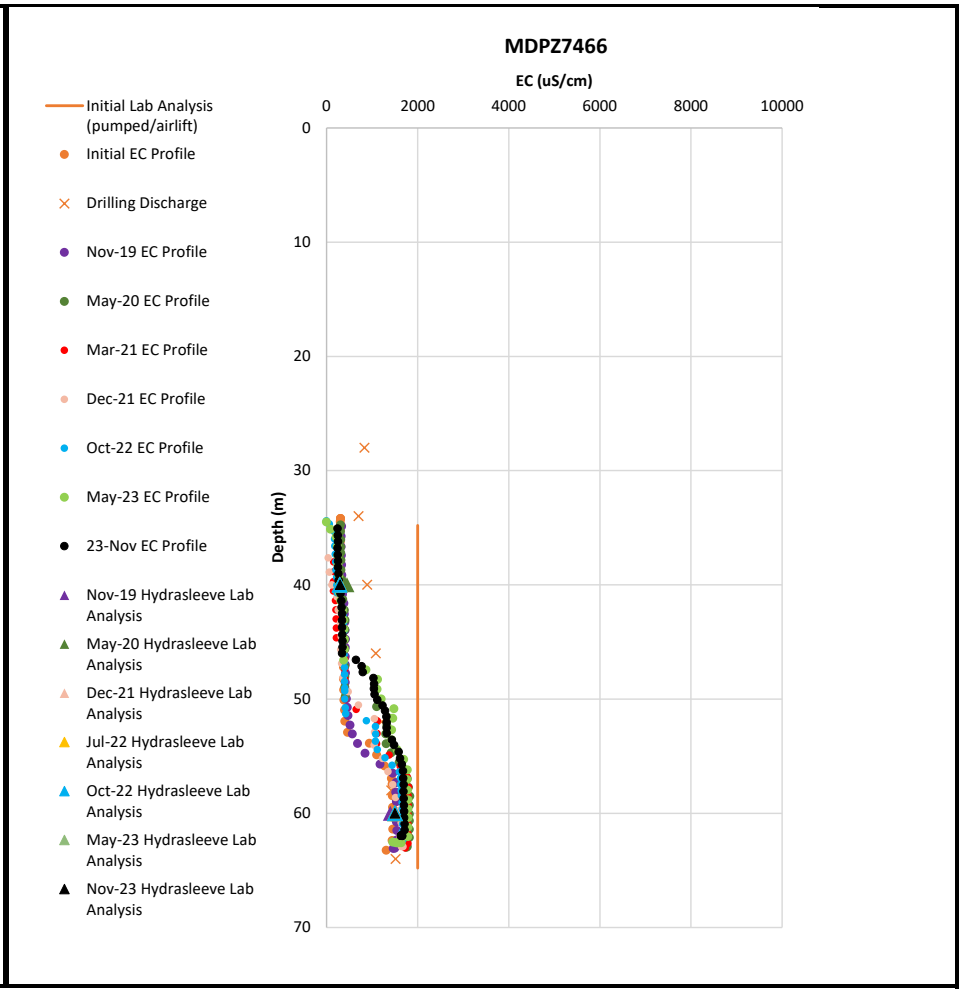

MDPZ7461
EC (uS/cm)
0
2000
4000
6000
8000
10000
12000
14000
Depth (m)
0
20
40
60
80
100
120
140
Initial Lab Analysis (pumped/airlift)
Initial EC Profile
Drilling Discharge
Nov-19 EC Profile
May-20 EC Profile
Aug-21 EC Profile
Dec-21 EC Profile
July-22 EC Profile
Oct-22 EC Profile
May-23 EC Profile
Nov-23 EC Profile
Nov-19 Hydrasleeve Lab Analysis
May-20 Hydrasleeve Lab Analysis
Mar-21 Hydrasleeve Lab Analysis
Dec-21 Hydrasleeve Lab Analysis
Jul-22 Hydrasleeve Lab Analysis
Oct-22 Hydrasleeve Lab Analysis
May-23 Hydrasleeve Lab Analysis
Nov-23 Hydrasleeve Lab Analysis

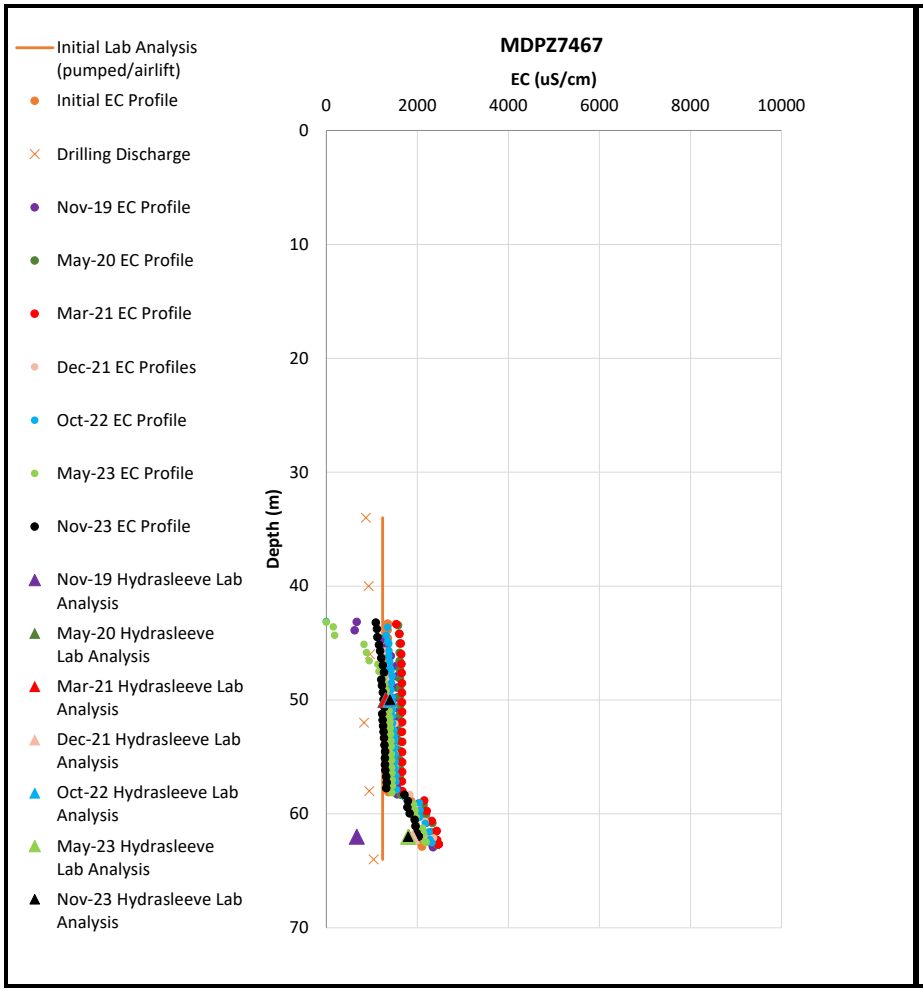

MDPZ7462
EC (uS/cm)
0
3000
6000
9000
12000
15000
18000
Depth (m)
0
20
40
60
80
100
120
140
Initial Lab Analysis (pumped/airlift)
Initial EC Profile
Drilling Discharge
Nov-19 EC Profile
Nov-19 Hydrasleeve Lab Analysis
May-20 EC Profile
May-20 Hydrasleeve Lab Analysis

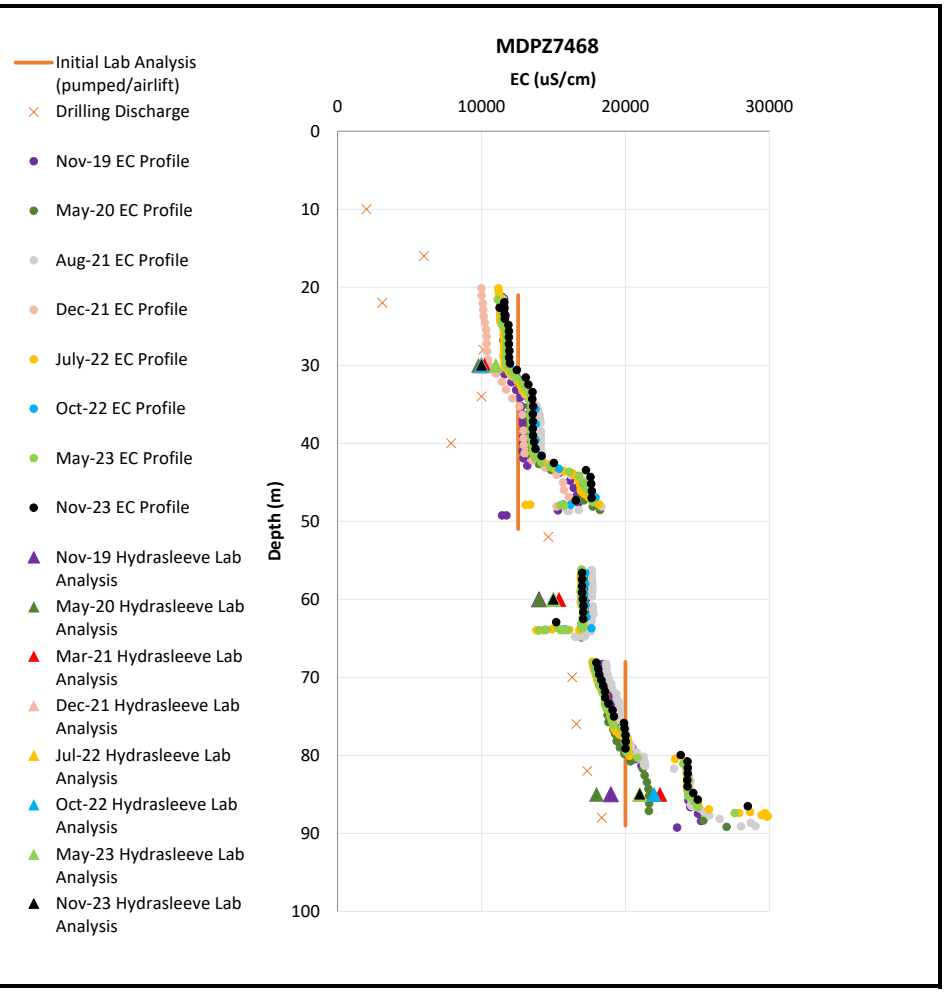

MDPZ7463
EC (uS/cm)
0
3000
6000
9000
12000
15000
Depth (m)
0
10
20
30
40
50
60
70
80
90
100
Initial Lab Analysis (pumped/airlift)
Initial EC Profile
Drilling Discharge
Nov-19 EC Profile
May-20 EC Profile
Mar-21 EC Profile
Dec-21 EC Profile
July-22 EC Profile
Oct-22 EC Profile
May-23 EC Profile
Nov-23 EC Profile
Nov-19 Hydrasleeve Lab Analysis
May-20 Hydrasleeve Lab Analysis
Mar-21 Hydrasleeve Lab Analysis
Dec-21 Hydrasleeve Lab Analysis
Jul-22 Hydrasleeve Lab Analysis
Oct-22 Hydrasleeve Lab Analysis
May-23 Hydrasleeve Lab Analysis
Nov-23 Hydrasleeve Lab Analysis

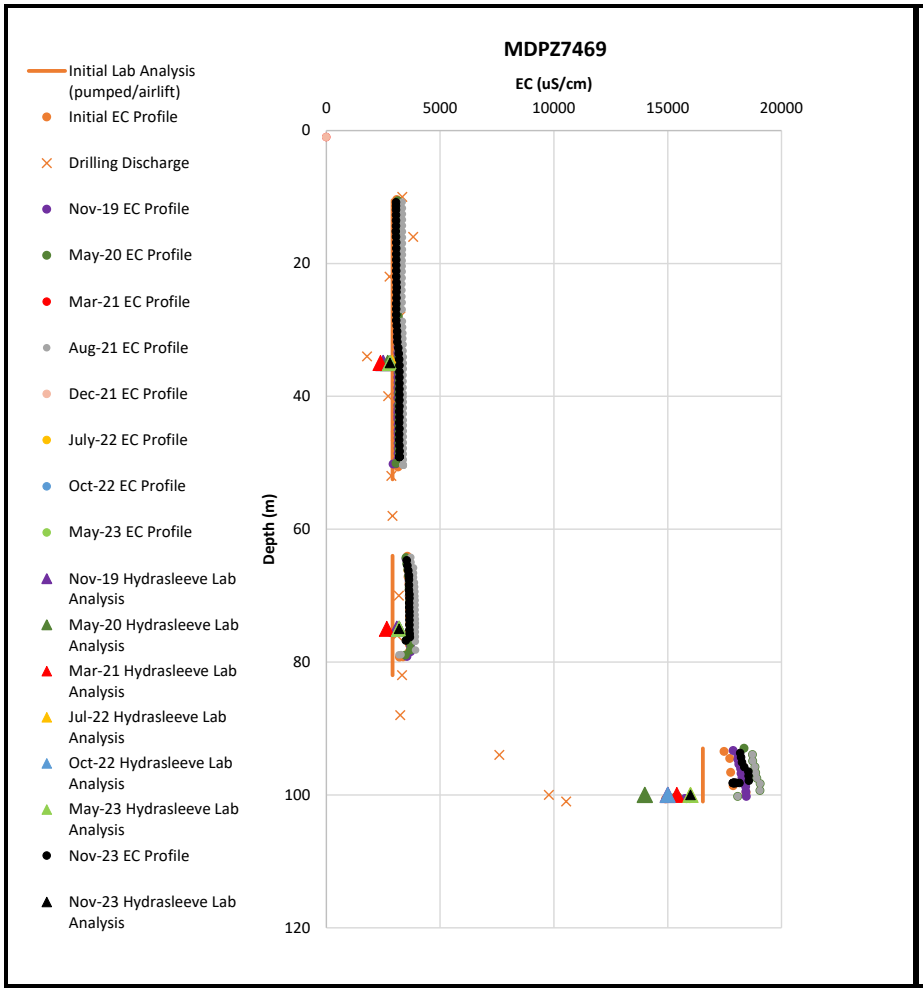

MDPZ7464
EC (uS/cm)
0
3000
6000
9000
12000
15000
18000
21000
Depth (m)
0
10
20
30
40
50
60
70
80
90
100
Initial Lab Analysis (pumped/airlift)
Initial EC Profile
Drilling Discharge
Nov-19 EC Profile
May-20 EC Profile
Mar-21 EC Profile
July-22 EC Profile
Oct-22 EC Profile
May-23 EC Profile
Nov-23 EC Profile
Nov-19 Hydrasleeve Lab Analysis
May-20 Hydrasleeve Lab Analysis
Mar-21 Hydrasleeve Lab Analysis
Dec-21 Hydrasleeve Lab Analysis
Jul-22 Hydrasleeve Lab Analysis
Oct-22 Hydrasleeve Lab Analysis
May-23 Hydrasleeve Lab Analysis
Nov-23 Hydrasleeve Lab Analysis

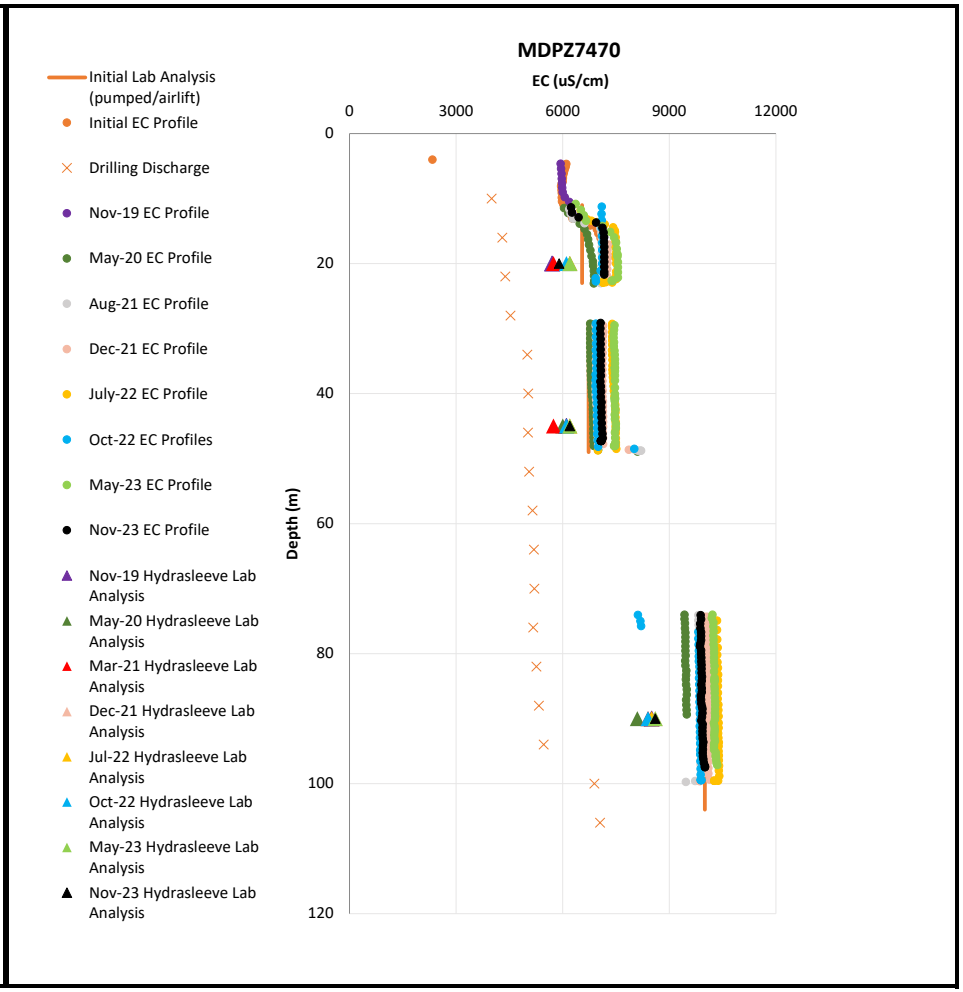

MDPZ7465
EC (uS/cm)
0
2000
4000
6000
8000
10000
Depth (m)
0
20
40
60
80
100
120
Initial Lab Analysis (pumped/airlift)
Initial EC Profile
Drilling Discharge
Nov-19 EC Profile
May-20 EC Profile
Dec-21 EC Profile
Oct-22 EC Profile
May-23 EC Profile
Nov-23 EC Profile
Nov-19 Hydrasleeve Lab Analysis
May-20 Hydrsleeve Lab Analysis
Jul-22 Hydrasleeve Lab Analysis
Oct-22 Hydrasleeve Lab Analysis
May-23 Hydrasleeve Lab Analysis
Nov-23 Hydrasleeve Lab Analysis

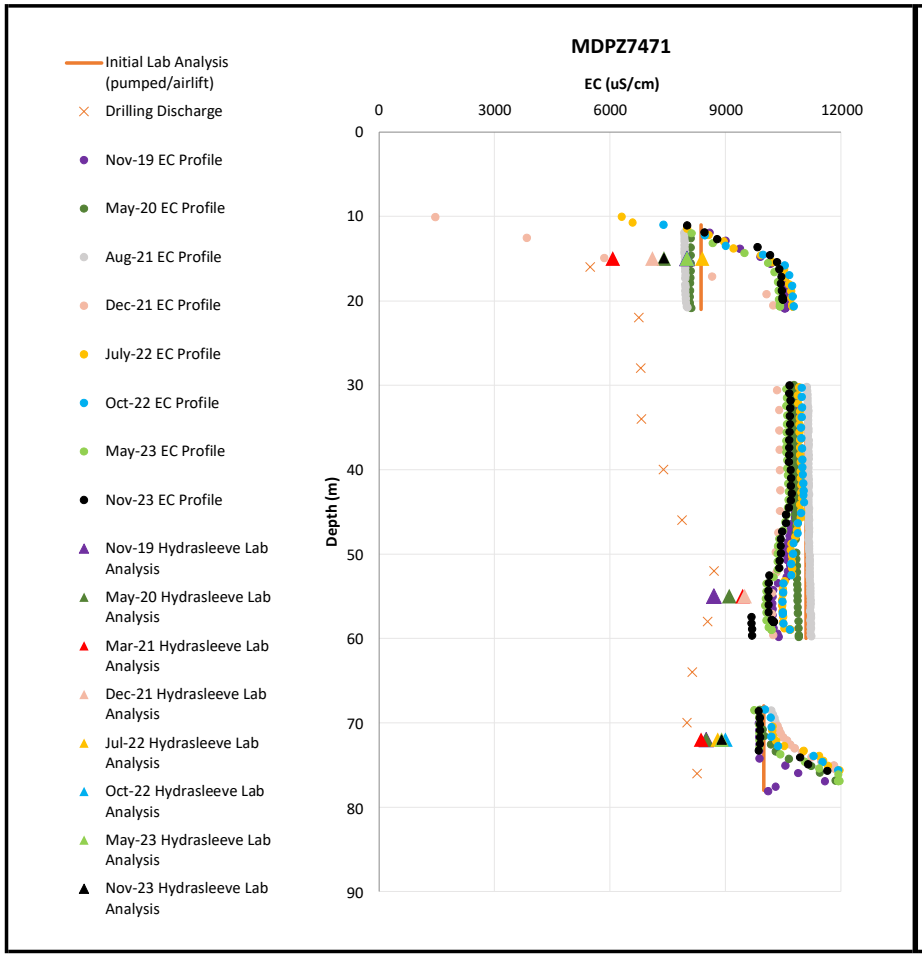

MDPZ7466
EC (uS/cm)
0
2000
4000
6000
8000
10000
Depth (m)
0
10
20
30
40
50
60
70
Initial Lab Analysis (pumped/airlift)
Initial EC Profile
Drilling Discharge
Nov-19 EC Profile
May-20 EC Profile
Mar-21 EC Profile
Dec-21 EC Profile
Oct-22 EC Profile
May-23 EC Profile
23-Nov EC Profile
Nov-19 Hydrasleeve Lab Analysis
May-20 Hydrasleeve Lab Analysis
Dec-21 Hydrasleeve Lab Analysis
Jul-22 Hydrasleeve Lab Analysis
Oct-22 Hydrasleeve Lab Analysis
May-23 Hydrasleeve Lab Analysis
Nov-23 Hydrasleeve Lab Analysis

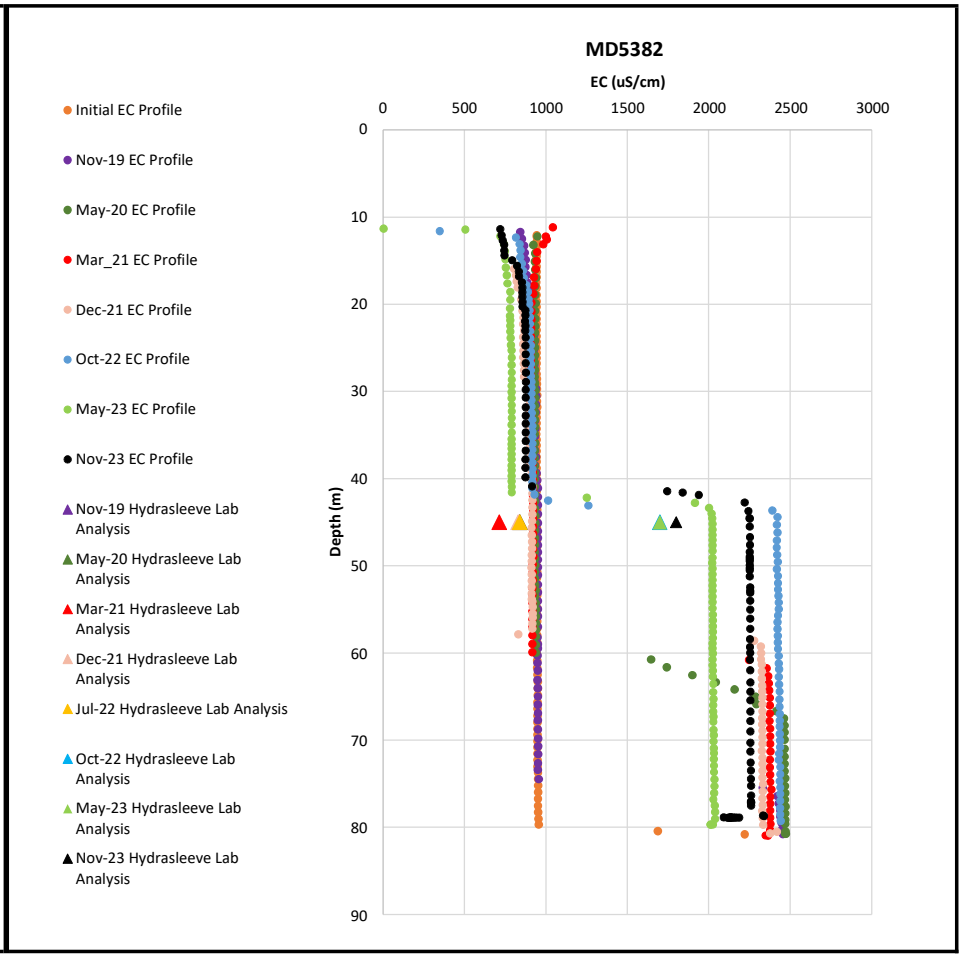

MDPZ7467
EC (uS/cm)
0
2000
4000
6000
8000
10000
Depth (m)
0
10
20
30
40
50
60
70
Initial Lab Analysis (pumped/airlift)
Initial EC Profile
Drilling Discharge
Nov-19 EC Profile
May-20 EC Profile
Mar-21 EC Profile
Dec-21 EC Profiles
Oct-22 EC Profile
May-23 EC Profile
Nov-23 EC Profile
Nov-19 Hydrasleeve Lab Analysis
May-20 Hydrasleeve Lab Analysis
Mar-21 Hydrasleeve Lab Analysis
Dec-21 Hydrasleeve Lab Analysis
Oct-22 Hydrasleeve Lab Analysis
May-23 Hydrasleeve Lab Analysis
Nov-23 Hydrasleeve Lab Analysis

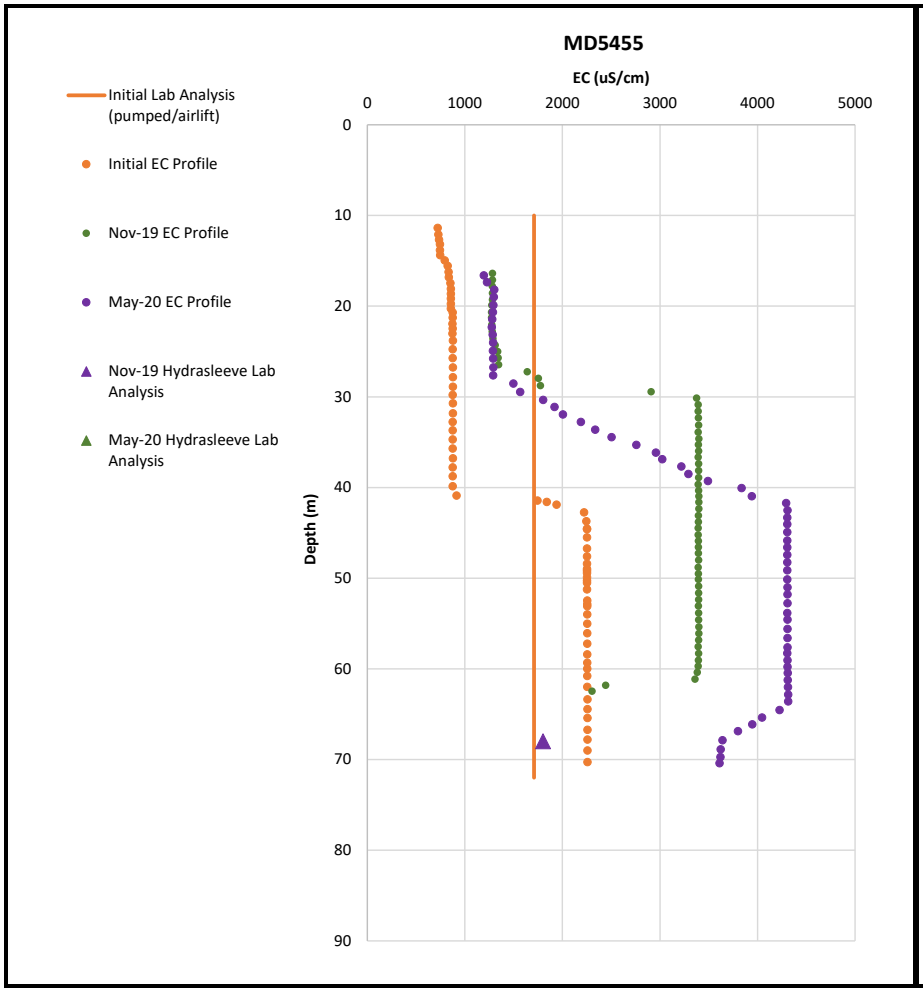

MDPZ7468
EC (uS/cm)
0
10000
20000
30000
Depth (m)
0
10
20
30
40
50
60
70
80
90
100
Initial Lab Analysis (pumped/airlift)
Drilling Discharge
Nov-19 EC Profile
May-20 EC Profile
Aug-21 EC Profile
Dec-21 EC Profile
July-22 EC Profile
Oct-22 EC Profile
May-23 EC Profile
Nov-23 EC Profile
Nov-19 Hydrasleeve Lab Analysis
May-20 Hydrasleeve Lab Analysis
Mar-21 Hydrasleeve Lab Analysis
Dec-21 Hydrasleeve Lab Analysis
Jul-22 Hydrasleeve Lab Analysis
Oct-22 Hydrasleeve Lab Analysis
May-23 Hydrasleeve Lab Analysis
Nov-23 Hydrasleeve Lab Analysis

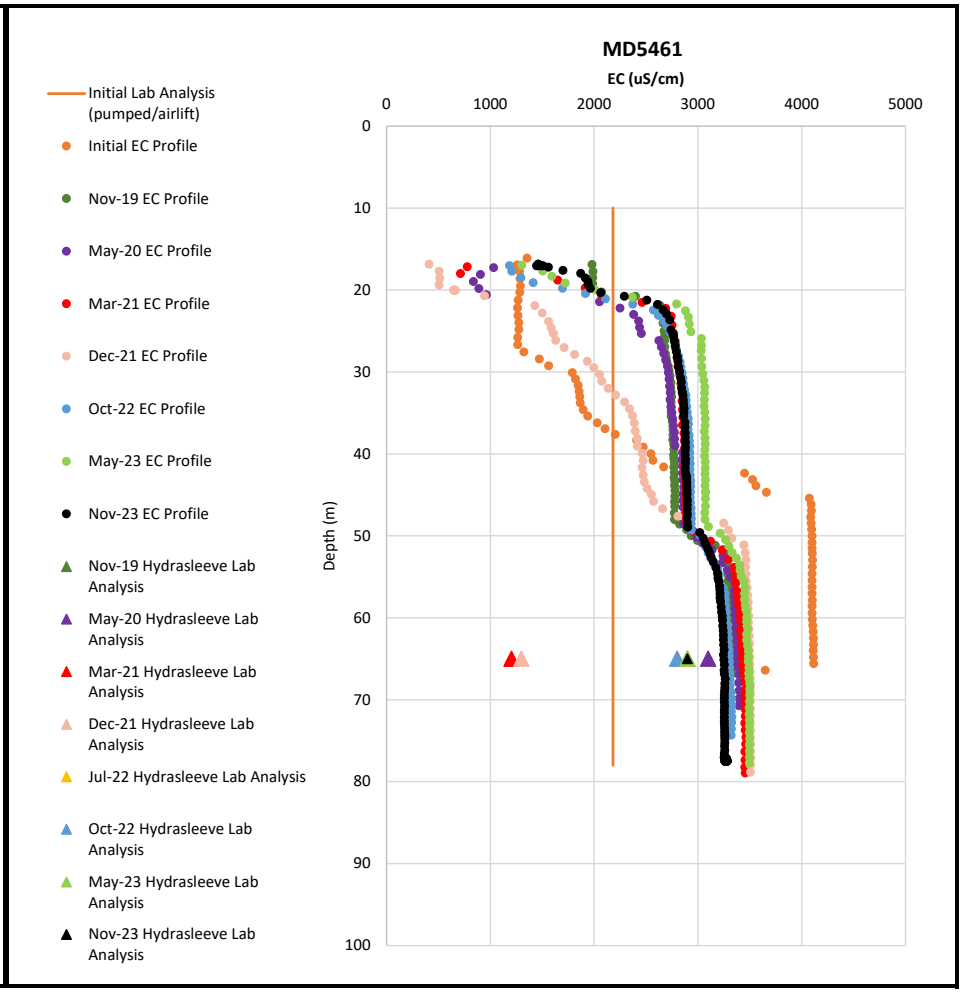

MDPZ7469
EC (uS/cm)
0
5000
10000
15000
20000
Depth (m)
0
20
40
60
80
100
120
Initial Lab Analysis (pumped/airlift)
Initial EC Profile
Drilling Discharge
Nov-19 EC Profile
May-20 EC Profile
Mar-21 EC Profile
Aug-21 EC Profile
Dec-21 EC Profile
July-22 EC Profile
Oct-22 EC Profile
May-23 EC Profile
Nov-19 Hydrasleeve Lab Analysis
May-20 Hydrasleeve Lab Analysis
Mar-21 Hydrasleeve Lab Analysis
Jul-22 Hydrasleeve Lab Analysis
Oct-22 Hydrasleeve Lab Analysis
May-23 Hydrasleeve Lab Analysis
Nov-23 EC Profile
Nov-23 Hydrasleeve Lab Analysis

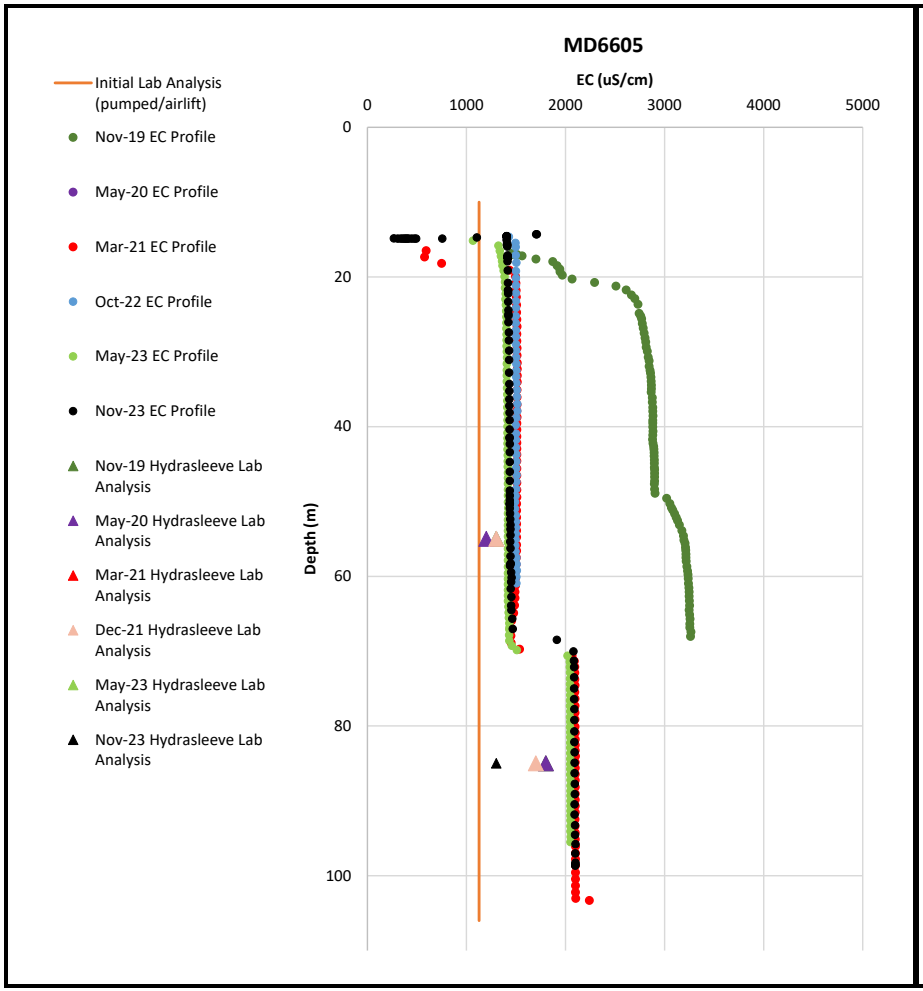

MDPZ7470
EC (uS/cm)
0
3000
6000
9000
12000
Depth (m)
0
20
40
60
80
100
120
Initial Lab Analysis (pumped/airlift)
Initial EC Profile
Drilling Discharge
Nov-19 EC Profile
May-20 EC Profile
Aug-21 EC Profile
Dec-21 EC Profile
July-22 EC Profile
Oct-22 EC Profiles
May-23 EC Profile
Nov-23 EC Profile
Nov-19 Hydrasleeve Lab Analysis
May-20 Hydrasleeve Lab Analysis
Mar-21 Hydrasleeve Lab Analysis
Dec-21 Hydrasleeve Lab Analysis
Jul-22 Hydrasleeve Lab Analysis
Oct-22 Hydrasleeve Lab Analysis
May-23 Hydrasleeve Lab Analysis
Nov-23 Hydrasleeve Lab Analysis

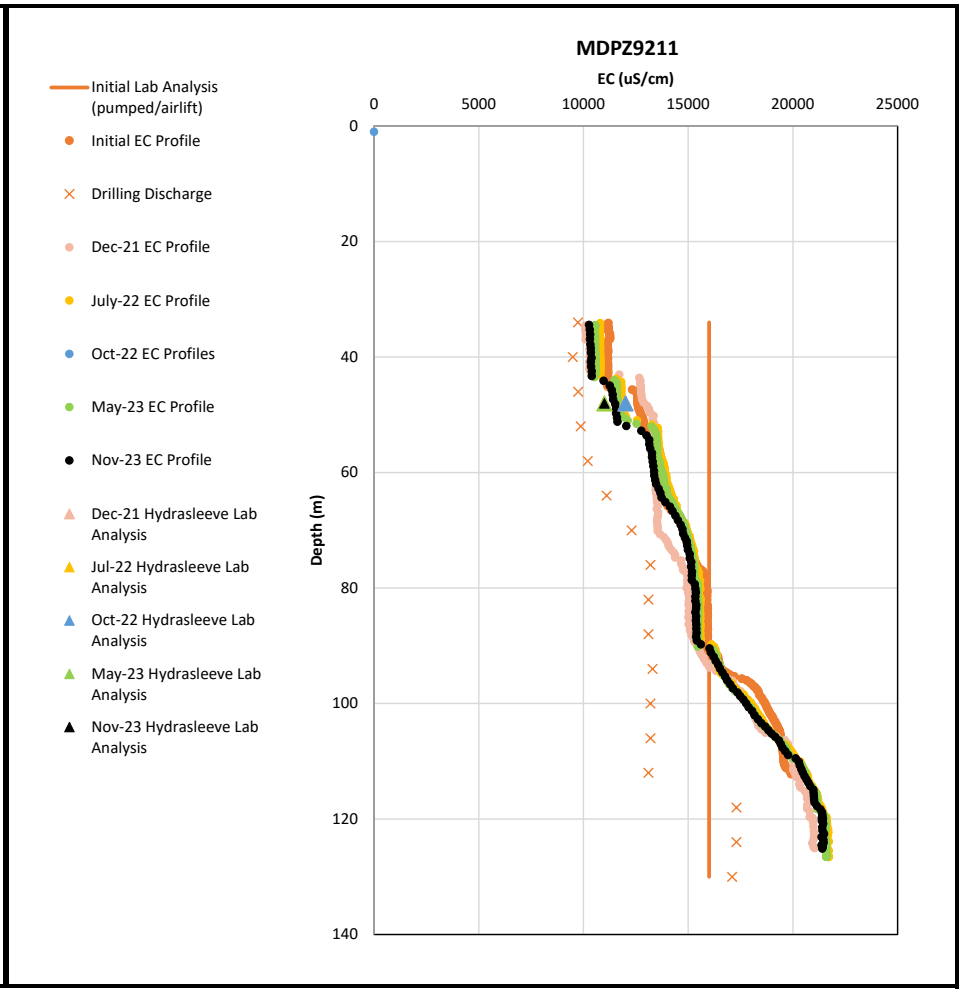

MDPZ7471
EC (uS/cm)
0
3000
6000
9000
12000
Depth (m)
0
10
20
30
40
50
60
70
80
90
Initial Lab Analysis (pumped/airlift)
Drilling Discharge
Nov-19 EC Profile
May-20 EC Profile
Aug-21 EC Profile
Dec-21 EC Profile
July-22 EC Profile
Oct-22 EC Profile
May-23 EC Profile
Nov-23 EC Profile
Nov-19 Hydrasleeve Lab Analysis
May-20 Hydrasleeve Lab Analysis
Mar-21 Hydrasleeve Lab Analysis
Dec-21 Hydrasleeve Lab Analysis
Jul-22 Hydrasleeve Lab Analysis
Oct-22 Hydrasleeve Lab Analysis
May-23 Hydrasleeve Lab Analysis
Nov-23 Hydrasleeve Lab Analysis

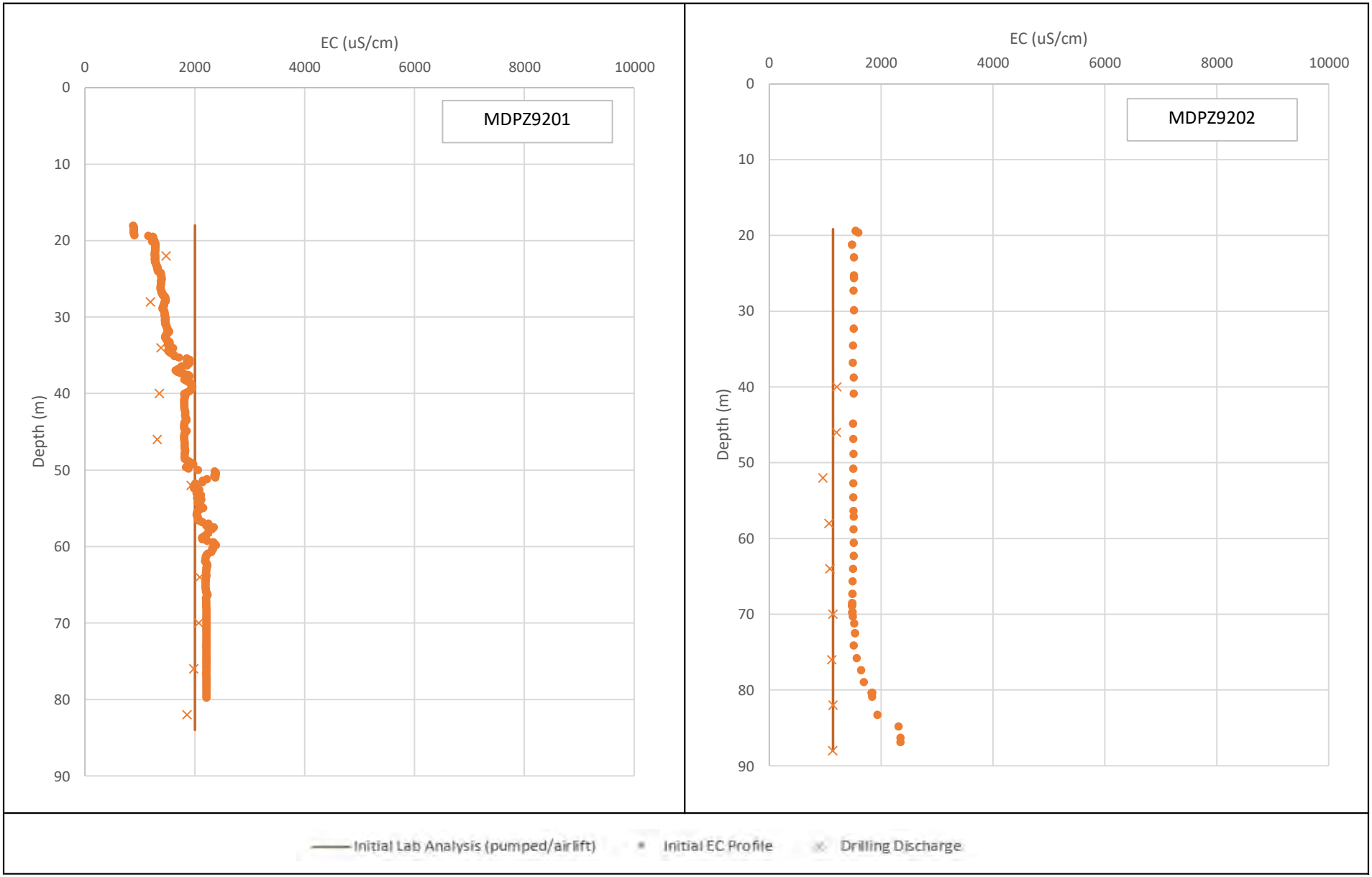

MD5382
EC (uS/cm)
0
500
1000
1500
2000
2500
3000
Depth (m)
0
10
20
30
40
50
60
70
80
90
Initial EC Profile
Nov-19 EC Profile
May-20 EC Profile
Mar_21 EC Profile
Dec-21 EC Profile
Oct-22 EC Profile
May-23 EC Profile
Nov-23 EC Profile
Nov-19 Hydrasleeve Lab Analysis
May-20 Hydrasleeve Lab Analysis
Mar-21 Hydrasleeve Lab Analysis
Dec-21 Hydrasleeve Lab Analysis
Jul-22 Hydrasleeve Lab Analysis
Oct-22 Hydrasleeve Lab Analysis
May-23 Hydrasleeve Lab Analysis
Nov-23 Hydrasleeve Lab Analysis


MD5455
EC (uS/cm)
0
1000
2000
3000
4000
5000
Depth (m)
0
10
20
30
40
50
60
70
80
90
Initial Lab Analysis (pumped/airlift)
Initial EC Profile
Nov-19 EC Profile
May-20 EC Profile
Nov-19 Hydrasleeve Lab Analysis
May-20 Hydrasleeve Lab Analysis

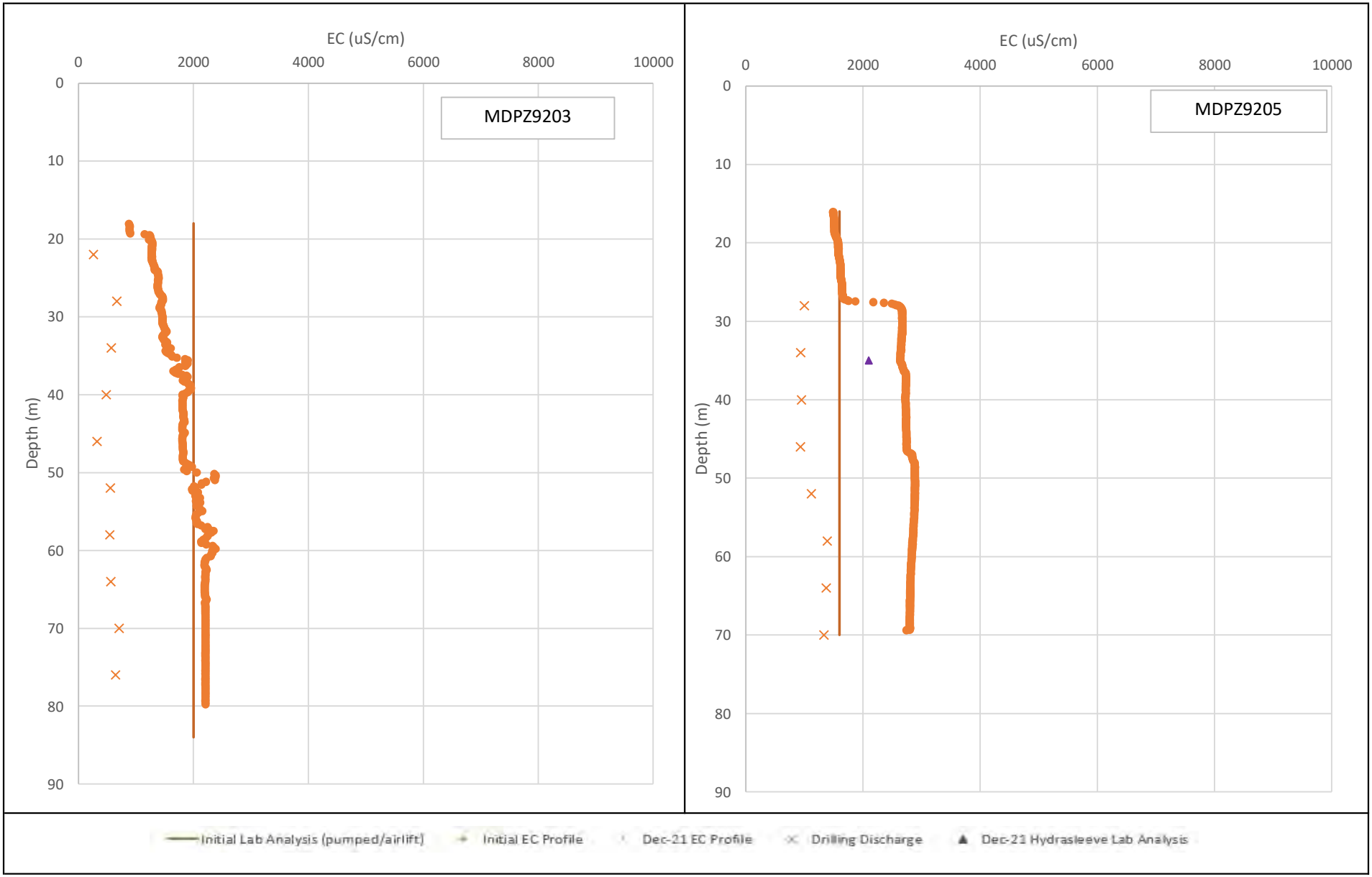

MD5461
EC (uS/cm)
0
1000
2000
3000
4000
5000
Depth (m)
0
10
20
30
40
50
60
70
80
90
100
Initial Lab Analysis (pumped/airlift)
Initial EC Profile
Nov-19 EC Profile
May-20 EC Profile
Mar-21 EC Profile
Dec-21 EC Profile
Oct-22 EC Profile
May-23 EC Profile
Nov-23 EC Profile
Nov-19 Hydrasleeve Lab Analysis
May-20 Hydrasleeve Lab Analysis
Mar-21 Hydrasleeve Lab Analysis
Dec-21 Hydrasleeve Lab Analysis
Jul-22 Hydrasleeve Lab Analysis
Oct-22 Hydrasleeve Lab Analysis
May-23 Hydrasleeve Lab Analysis
Nov-23 Hydrasleeve Lab Analysis


MD6605
EC (uS/cm)
0
1000
2000
3000
4000
5000
Depth (m)
0
20
40
60
80
100
Initial Lab Analysis (pumped/airlift)
Nov-19 EC Profile
May-20 EC Profile
Mar-21 EC Profile
Oct-22 EC Profile
May-23 EC Profile
Nov-23 EC Profile
Nov-19 Hydrasleeve Lab Analysis
May-20 Hydrasleeve Lab Analysis
Mar-21 Hydrasleeve Lab Analysis
Dec-21 Hydrasleeve Lab Analysis
May-23 Hydrasleeve Lab Analysis
Nov-23 Hydrasleeve Lab Analysis

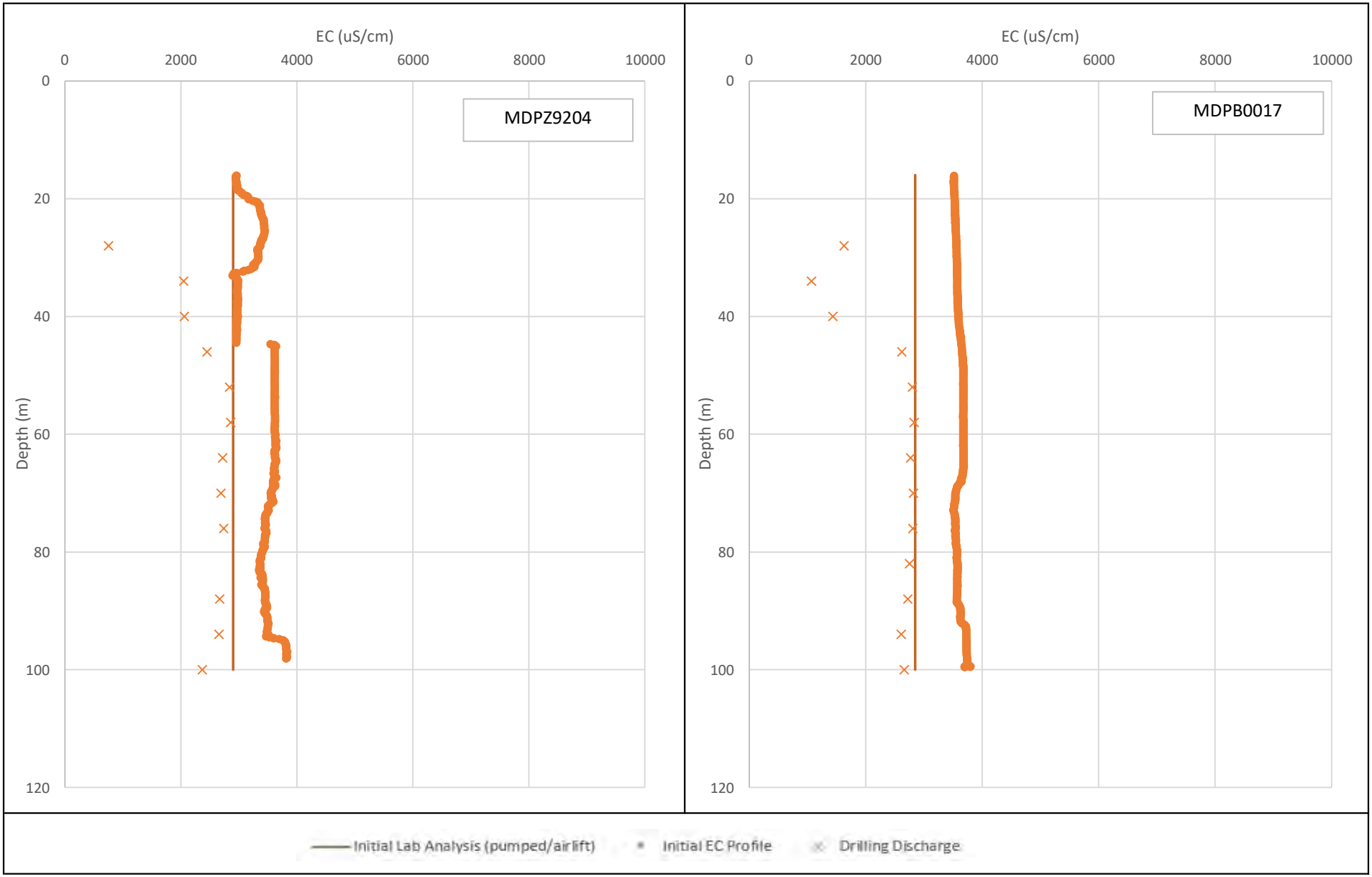

MDPZ9211
EC (uS/cm)
0
5000
10000
15000
20000
25000
Depth (m)
0
20
40
60
80
100
120
140
Initial Lab Analysis (pumped/airlift)
Initial EC Profile
Drilling Discharge
Dec-21 EC Profile
July-22 EC Profile
Oct-22 EC Profiles
May-23 EC Profile
Nov-23 EC Profile
Dec-21 Hydrasleeve Lab Analysis
Jul-22 Hydrasleeve Lab Analysis
Oct-22 Hydrasleeve Lab Analysis
May-23 Hydrasleeve Lab Analysis
Nov-23 Hydrasleeve Lab Analysis



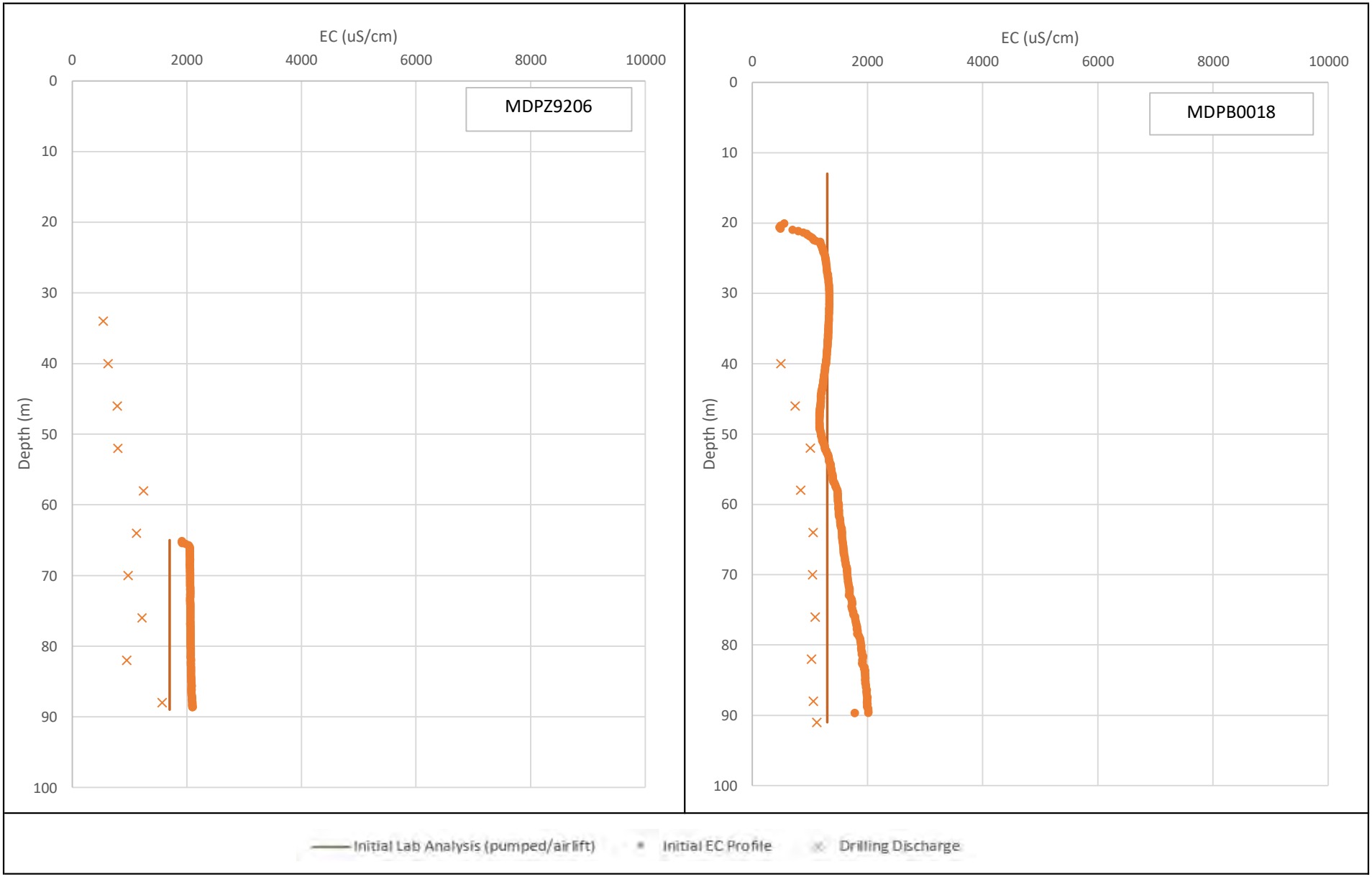
Salinity Plots: MDPZ9201 & MDPZ9202



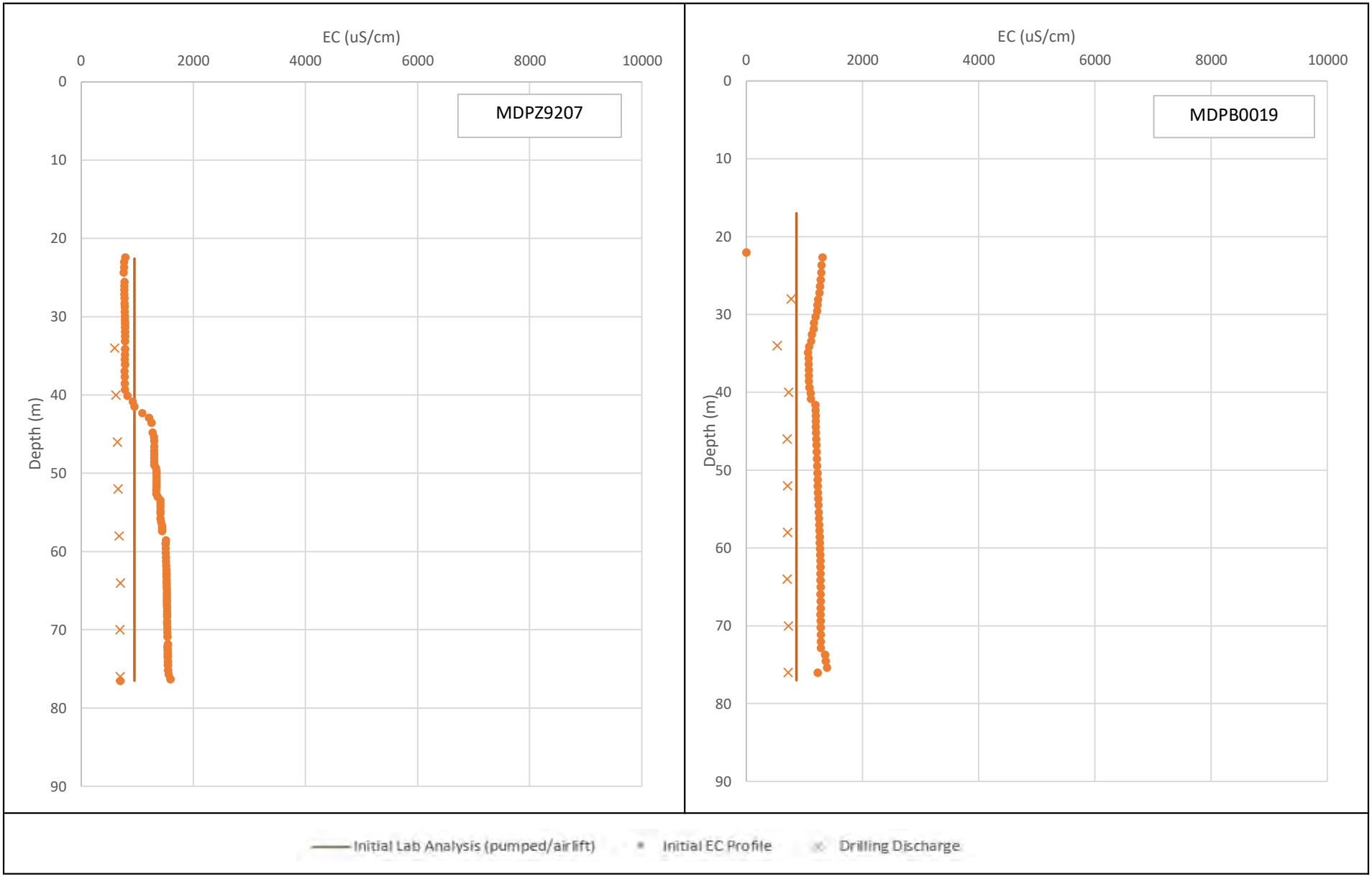
Salinity Plots: MDPZ9203 & MDPZ9205



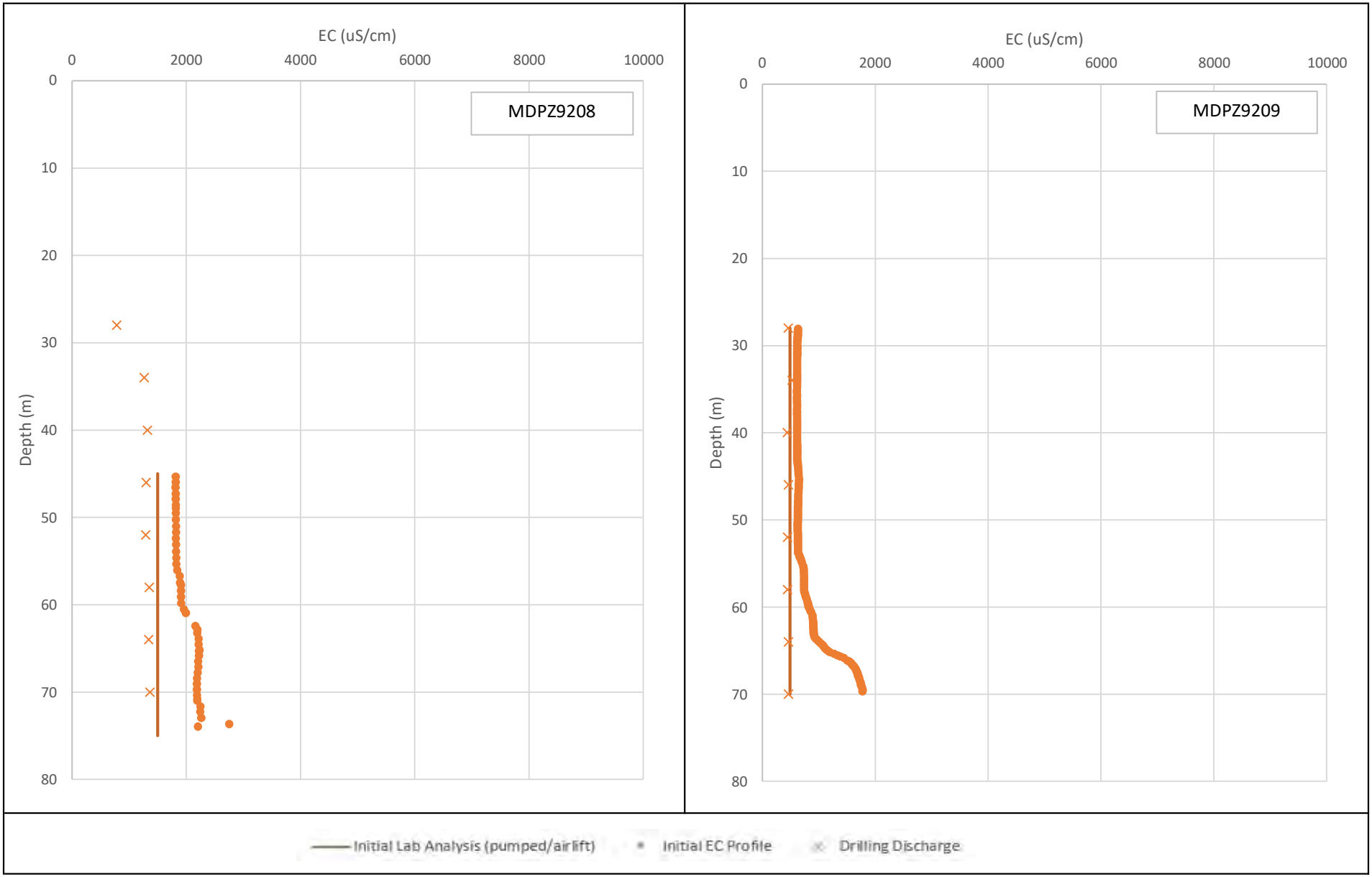
Salinity Plots: MDPZ9204 & MDPB0017



Salinity Plots: MDPZ9206 & MDPB0018



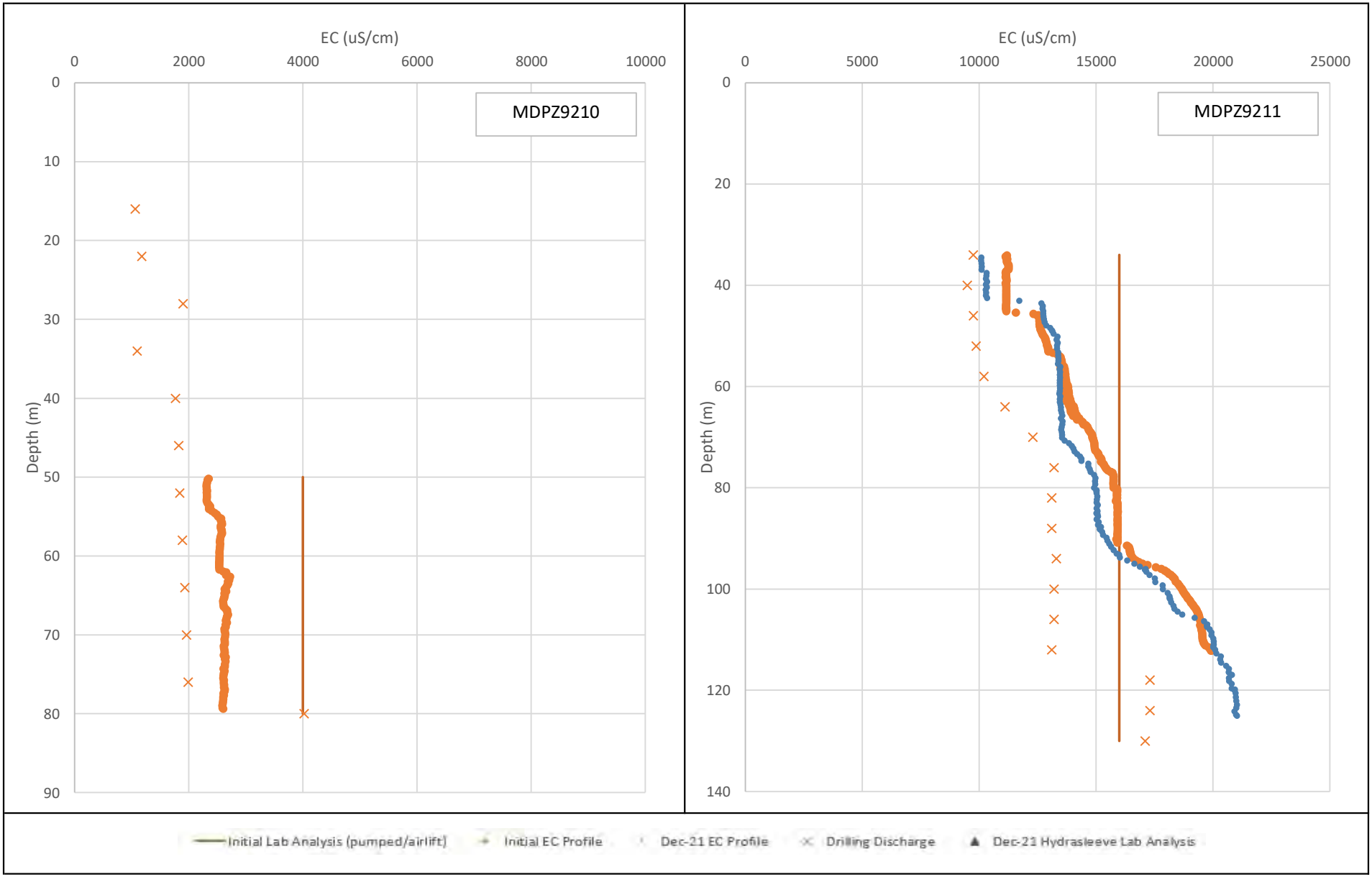
Salinity Plots: MDPZ9207 & MDPB0019



AQ2

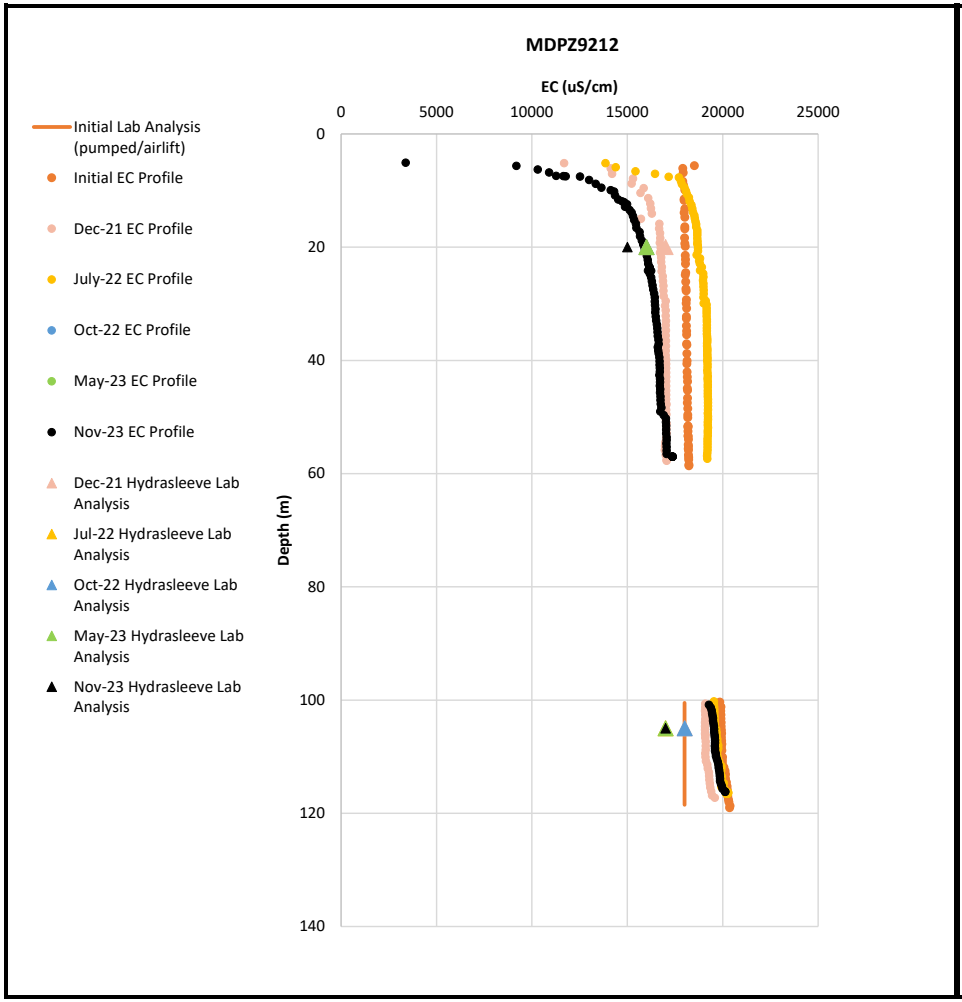
Salinity Plots: MDPZ9208 & MDPZ9209

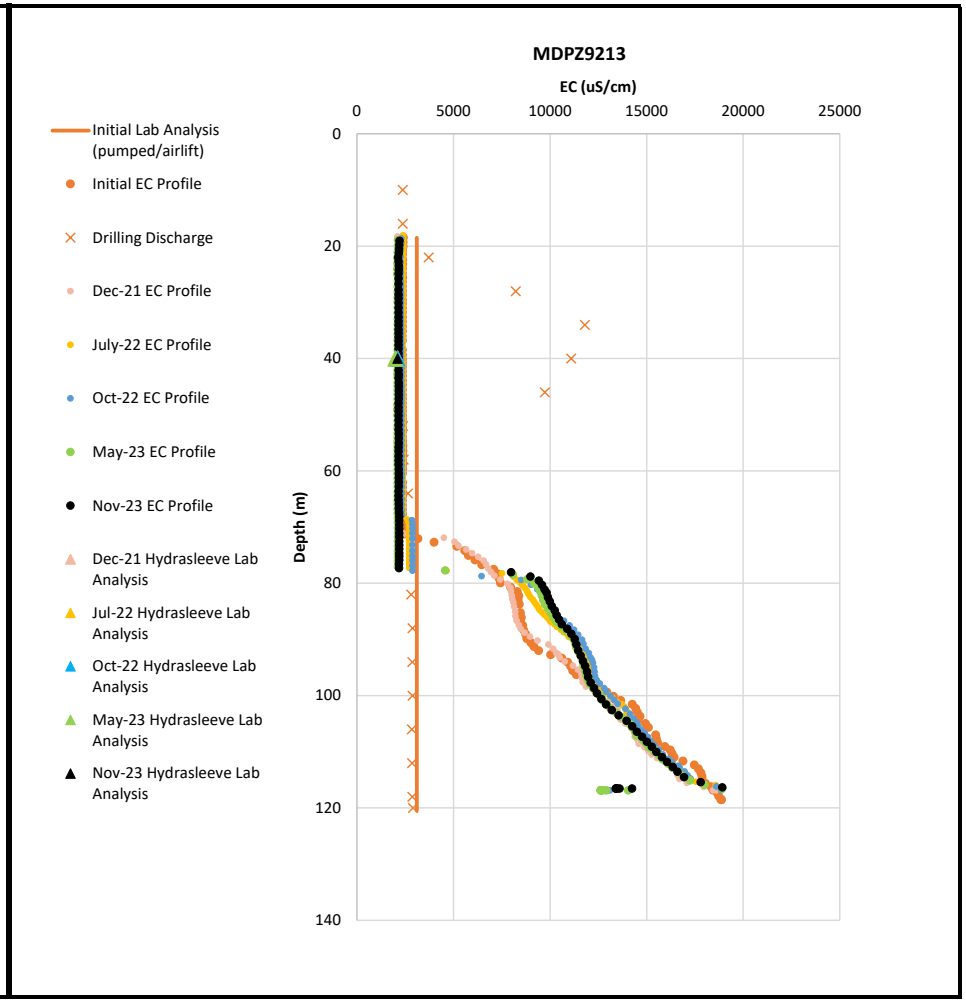
F:\171\3.C&R\Reports\492_Combined Baseline\Appendix H_Salinity Profile Plots\[EC_Combined_Graphs_PFS.xlsx]Fig 20

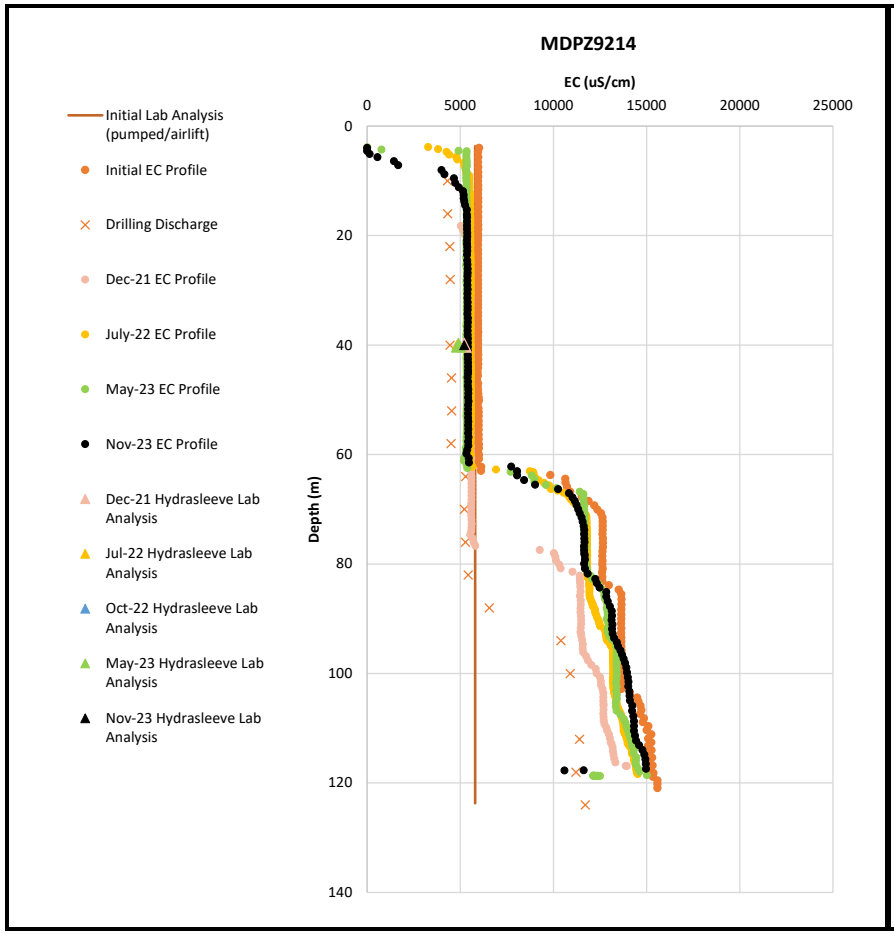


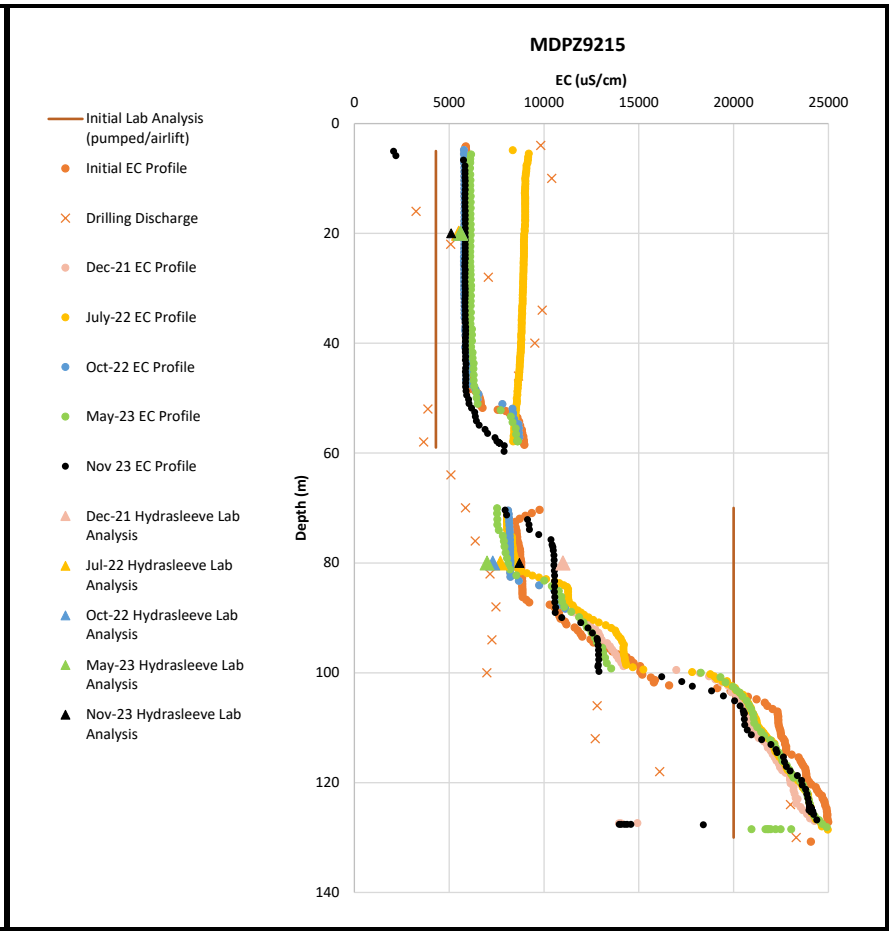
Salinity Plots: MDPZ9210 & MDPZ9211

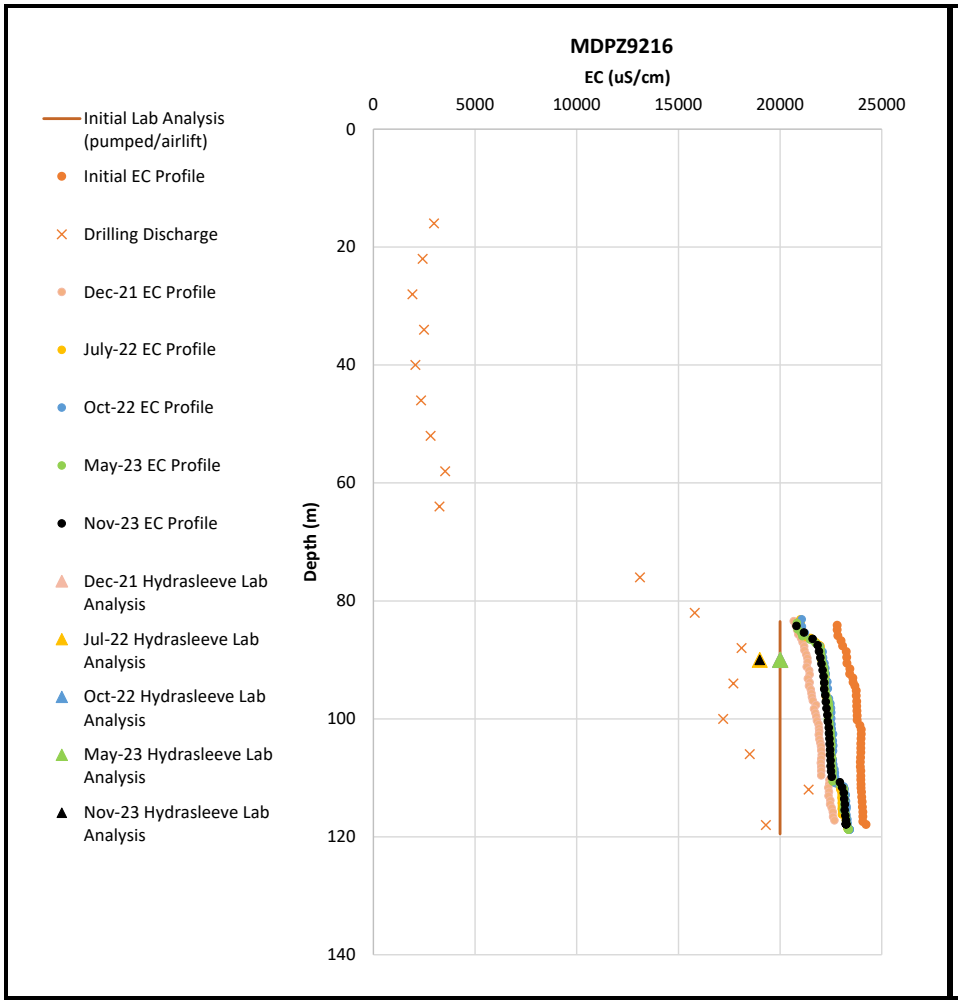
F:\171\3.C&R\Reports\492_Combined Baseline\Appendix H_Salinity Profile Plots\[EC_Combined_Graphs_PFS.xlsx]Fig 21

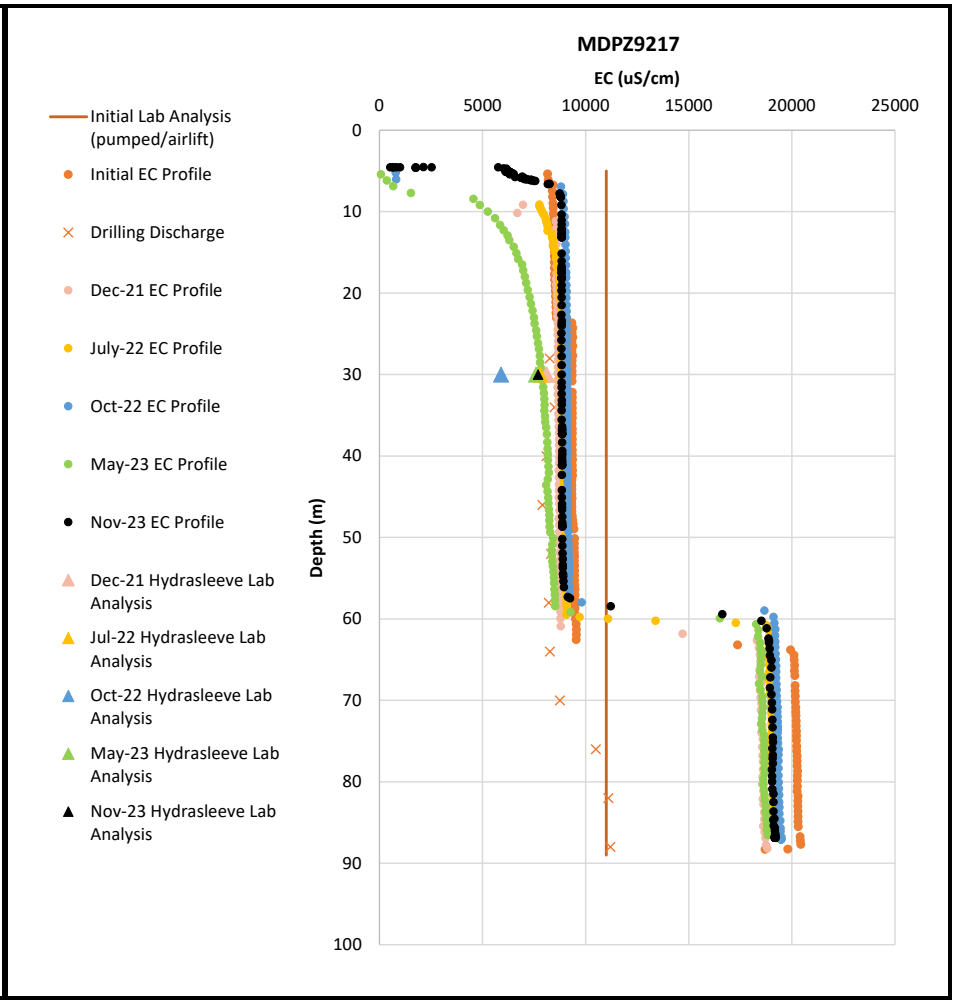

MDPZ9212
EC (uS/cm)
0
5000
10000
15000
20000
25000
Depth (m)
0
20
40
60
80
100
120
140
Initial Lab Analysis (pumped/airlift)
Initial EC Profile
Dec-21 EC Profile
July-22 EC Profile
Oct-22 EC Profile
May-23 EC Profile
Nov-23 EC Profile
Dec-21 Hydrasleeve Lab Analysis
Jul-22 Hydrasleeve Lab Analysis
Oct-22 Hydrasleeve Lab Analysis
May-23 Hydrasleeve Lab Analysis
Nov-23 Hydrasleeve Lab Analysis

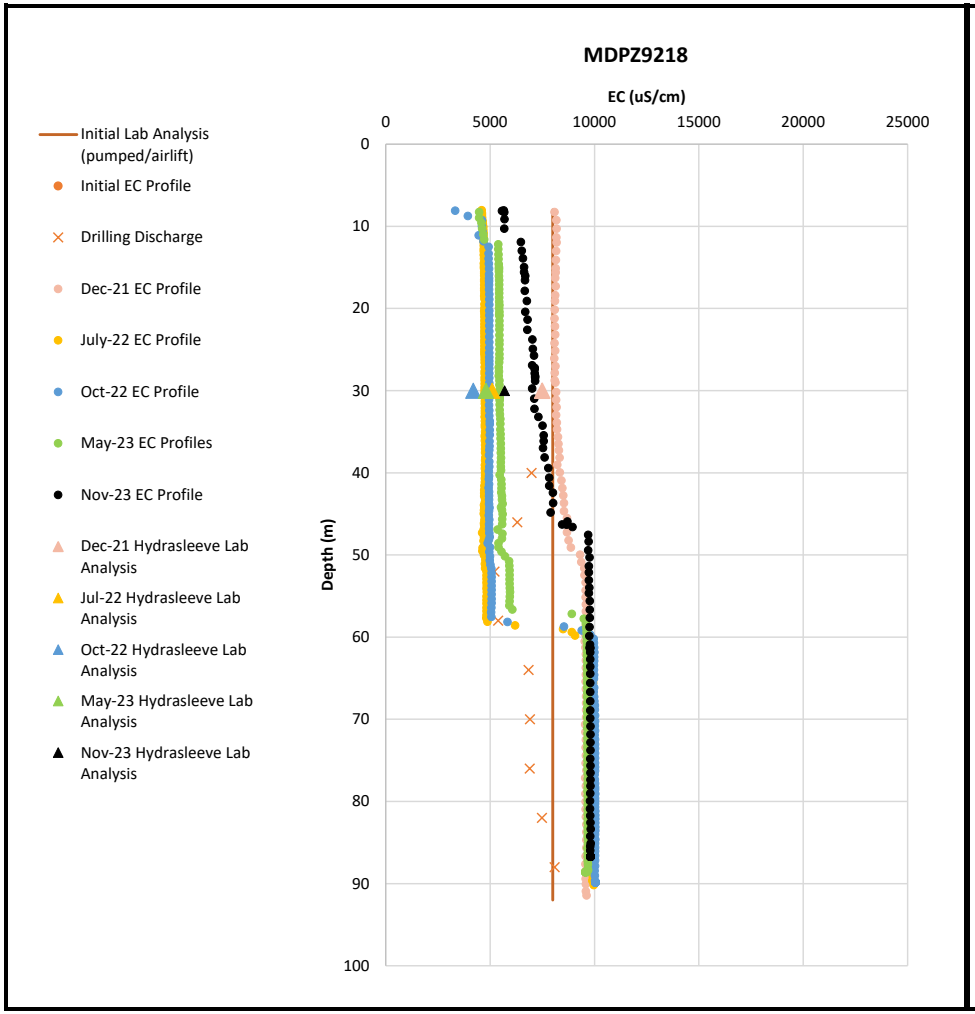

MDPZ9213
EC (uS/cm)
0
5000
10000
15000
20000
25000
Depth (m)
0
20
40
60
80
100
120
140
Initial Lab Analysis (pumped/airlift)
Initial EC Profile
Drilling Discharge
Dec-21 EC Profile
July-22 EC Profile
Oct-22 EC Profile
May-23 EC Profile
Nov-23 EC Profile
Dec-21 Hydrasleeve Lab Analysis
Jul-22 Hydrasleeve Lab Analysis
Oct-22 Hydrasleeve Lab Analysis
May-23 Hydrasleeve Lab Analysis
Nov-23 Hydrasleeve Lab Analysis

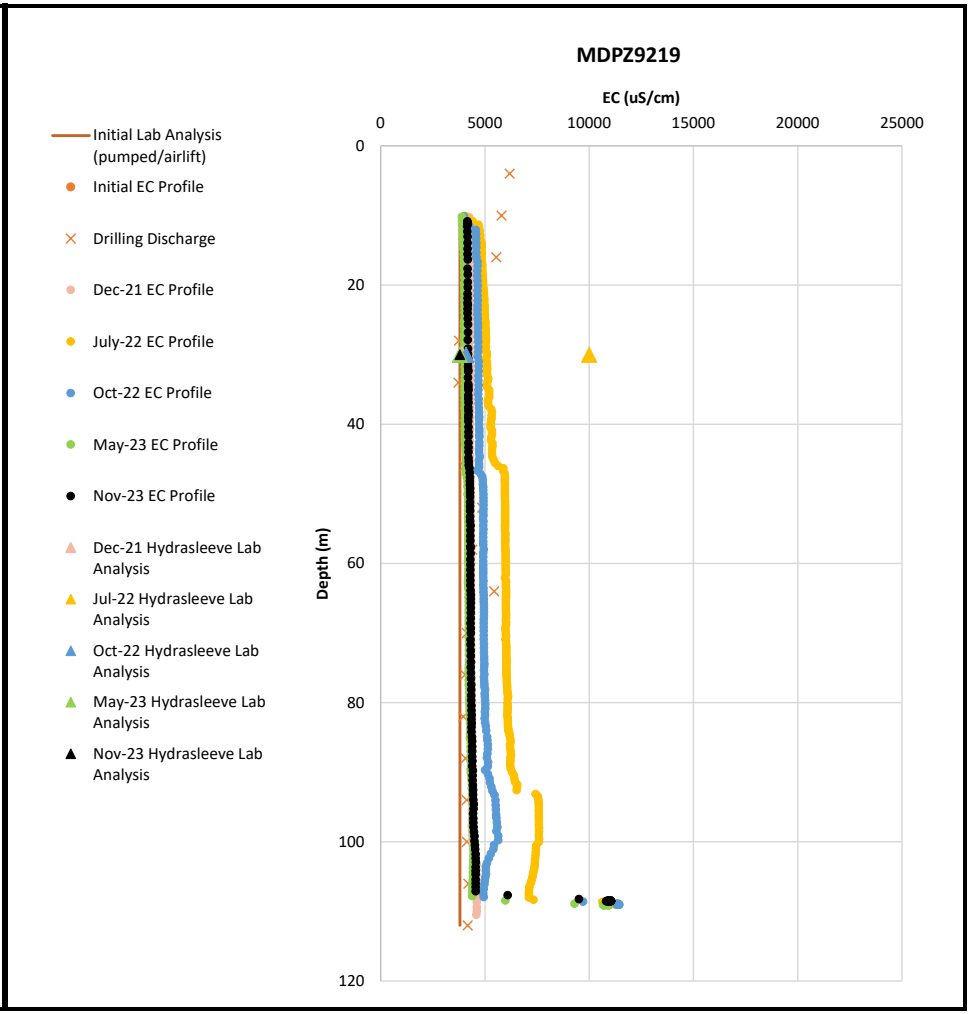

MDPZ9214
EC (uS/cm)
0
5000
10000
15000
20000
25000
Depth (m)
0
20
40
60
80
100
120
140
Initial Lab Analysis (pumped/airlift)
Initial EC Profile
Drilling Discharge
Dec-21 EC Profile
July-22 EC Profile
May-23 EC Profile
Nov-23 EC Profile
Dec-21 Hydrasleeve Lab Analysis
Jul-22 Hydrasleeve Lab Analysis
Oct-22 Hydrasleeve Lab Analysis
May-23 Hydrasleeve Lab Analysis
Nov-23 Hydrasleeve Lab Analysis

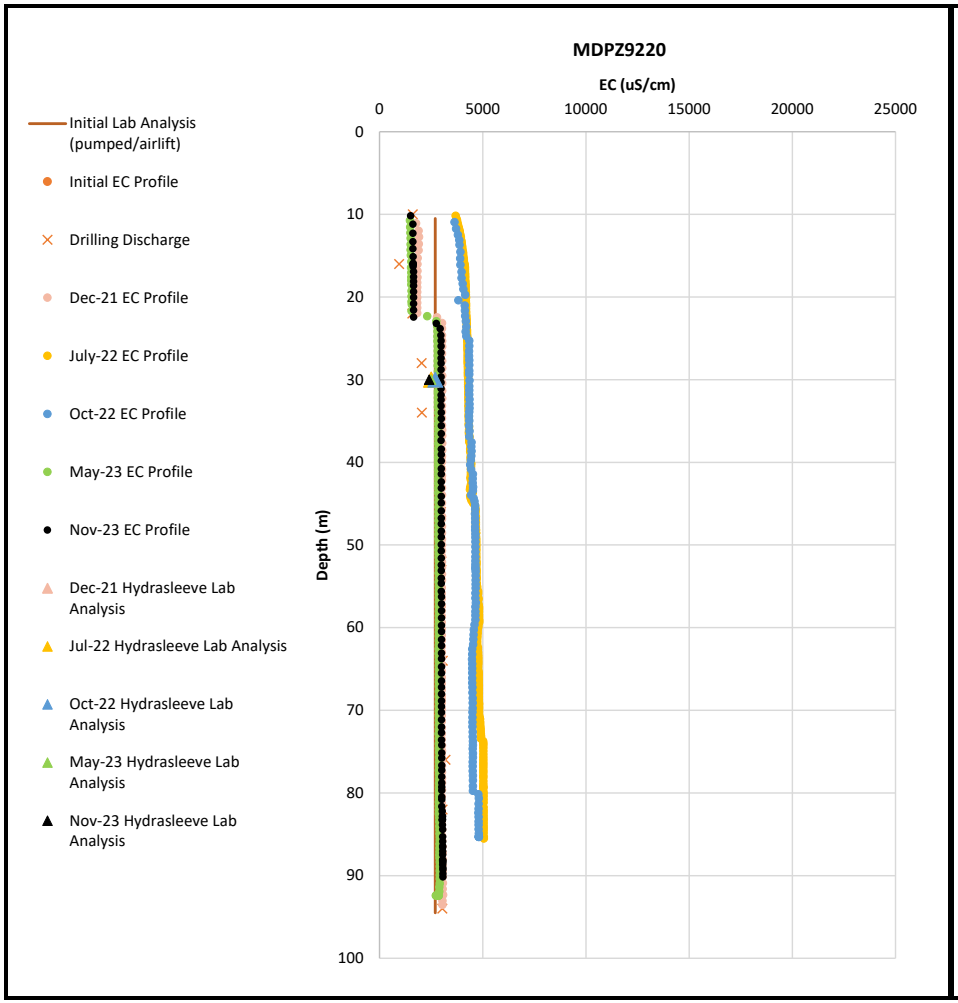

MDPZ9215
EC (uS/cm)
0
5000
10000
15000
20000
25000
Depth (m)
0
20
40
60
80
100
120
140
Initial Lab Analysis (pumped/airlift)
Initial EC Profile
Drilling Discharge
Dec-21 EC Profile
July-22 EC Profile
Oct-22 EC Profile
May-23 EC Profile
Nov 23 EC Profile
Dec-21 Hydrasleeve Lab Analysis
Jul-22 Hydrasleeve Lab Analysis
Oct-22 Hydrasleeve Lab Analysis
May-23 Hydrasleeve Lab Analysis
Nov-23 Hydrasleeve Lab Analysis

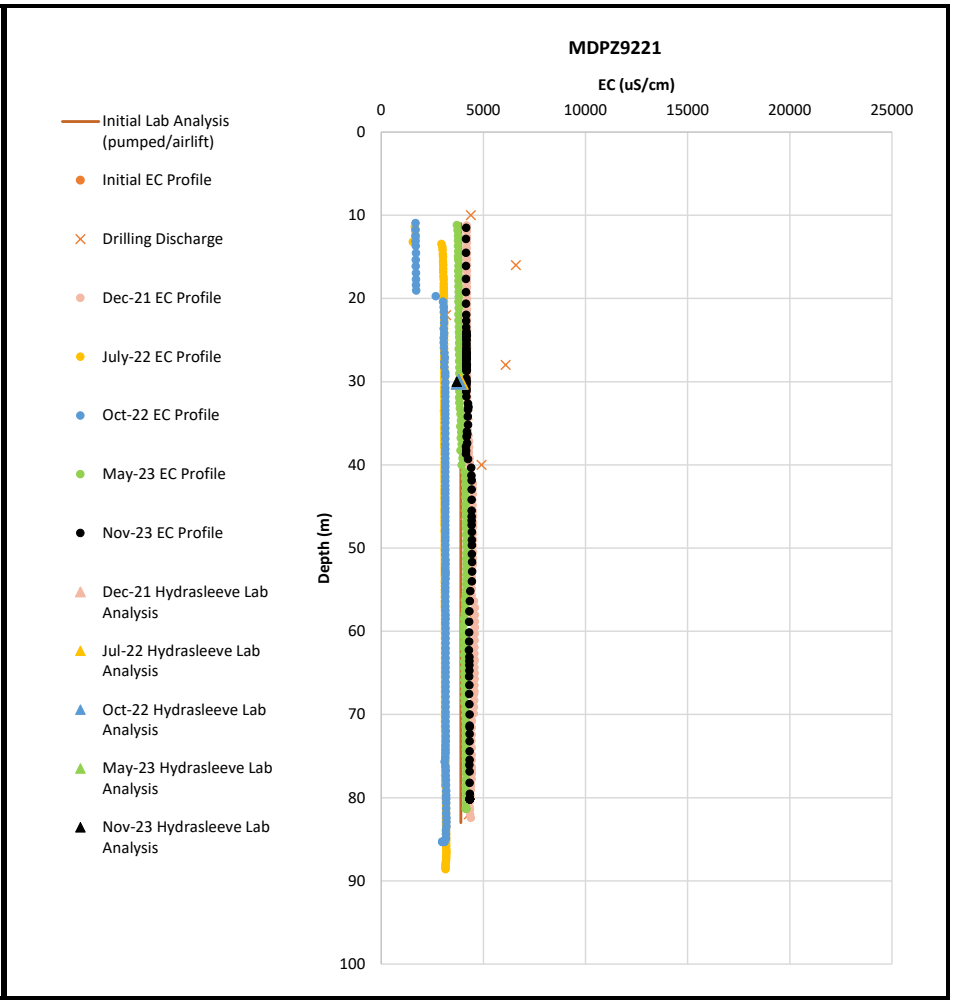

MDPZ9216
EC (uS/cm)
0
5000
10000
15000
20000
25000
Depth (m)
0
20
40
60
80
100
120
140
Initial Lab Analysis (pumped/airlift)
Initial EC Profile
Drilling Discharge
Dec-21 EC Profile
July-22 EC Profile
Oct-22 EC Profile
May-23 EC Profile
Nov-23 EC Profile
Dec-21 Hydrasleeve Lab Analysis
Jul-22 Hydrasleeve Lab Analysis
Oct-22 Hydrasleeve Lab Analysis
May-23 Hydrasleeve Lab Analysis
Nov-23 Hydrasleeve Lab Analysis

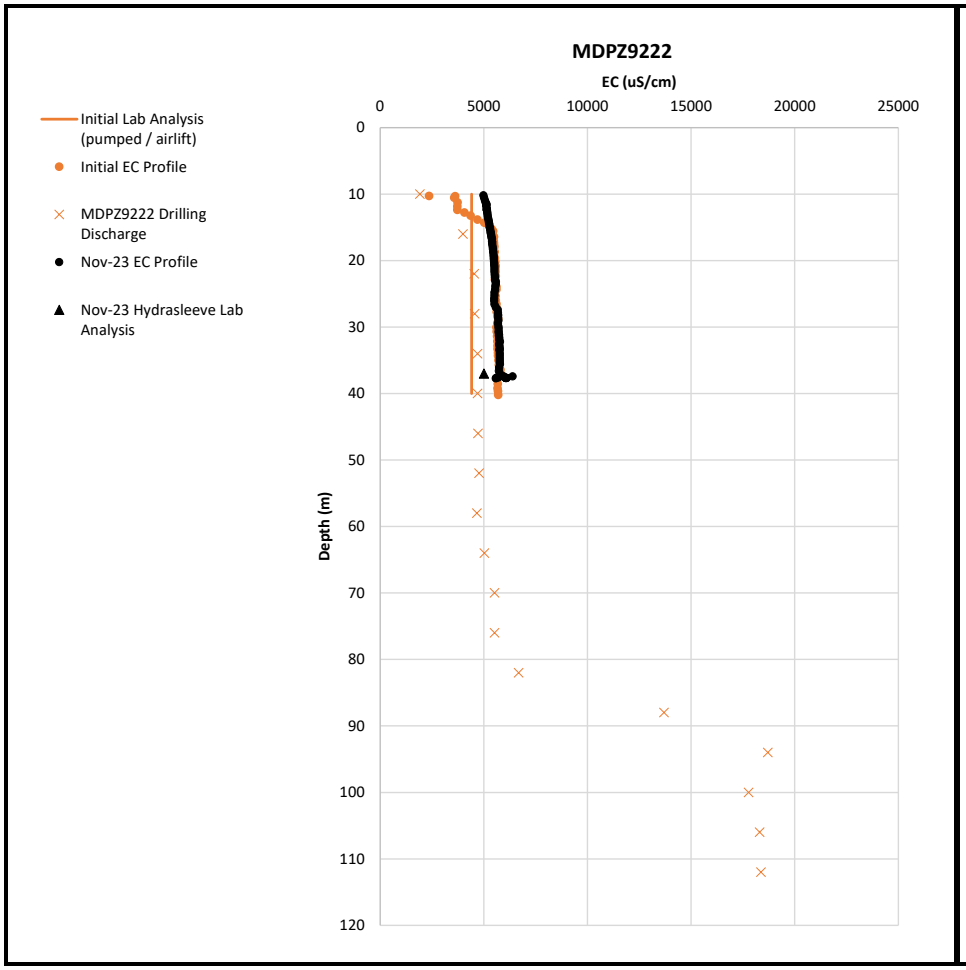

MDPZ9217
EC (uS/cm)
0
5000
10000
15000
20000
25000
Depth (m)
0
10
20
30
40
50
60
70
80
90
100
Initial Lab Analysis (pumped/airlift)
Initial EC Profile
Drilling Discharge
Dec-21 EC Profile
July-22 EC Profile
Oct-22 EC Profile
May-23 EC Profile
Nov-23 EC Profile
Dec-21 Hydrasleeve Lab Analysis
Jul-22 Hydrasleeve Lab Analysis
Oct-22 Hydrasleeve Lab Analysis
May-23 Hydrasleeve Lab Analysis
Nov-23 Hydrasleeve Lab Analysis

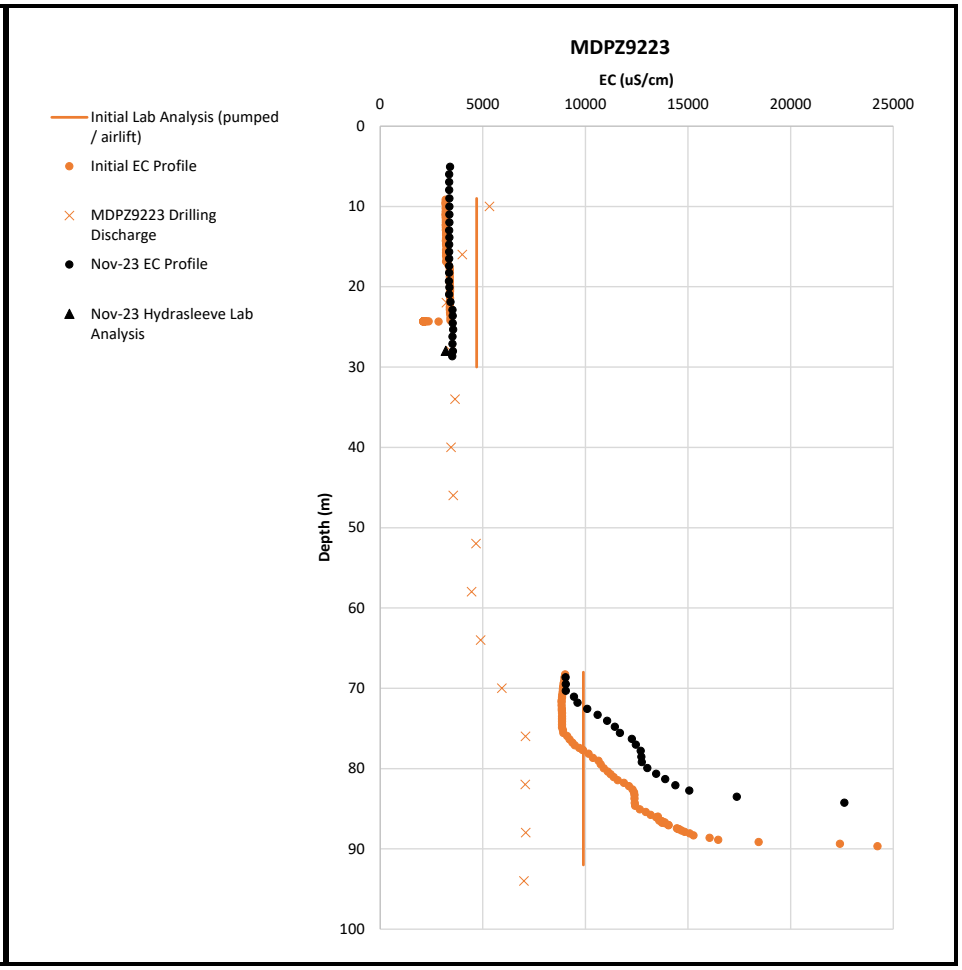

MDPZ9218
EC (uS/cm)
0
5000
10000
15000
20000
25000
Depth (m)
0
10
20
30
40
50
60
70
80
90
100
Initial Lab Analysis (pumped/airlift)
Initial EC Profile
Drilling Discharge
Dec-21 EC Profile
July-22 EC Profile
Oct-22 EC Profile
May-23 EC Profiles
Nov-23 EC Profile
Dec-21 Hydrasleeve Lab Analysis
Jul-22 Hydrasleeve Lab Analysis
Oct-22 Hydrasleeve Lab Analysis
May-23 Hydrasleeve Lab Analysis
Nov-23 Hydrasleeve Lab Analysis

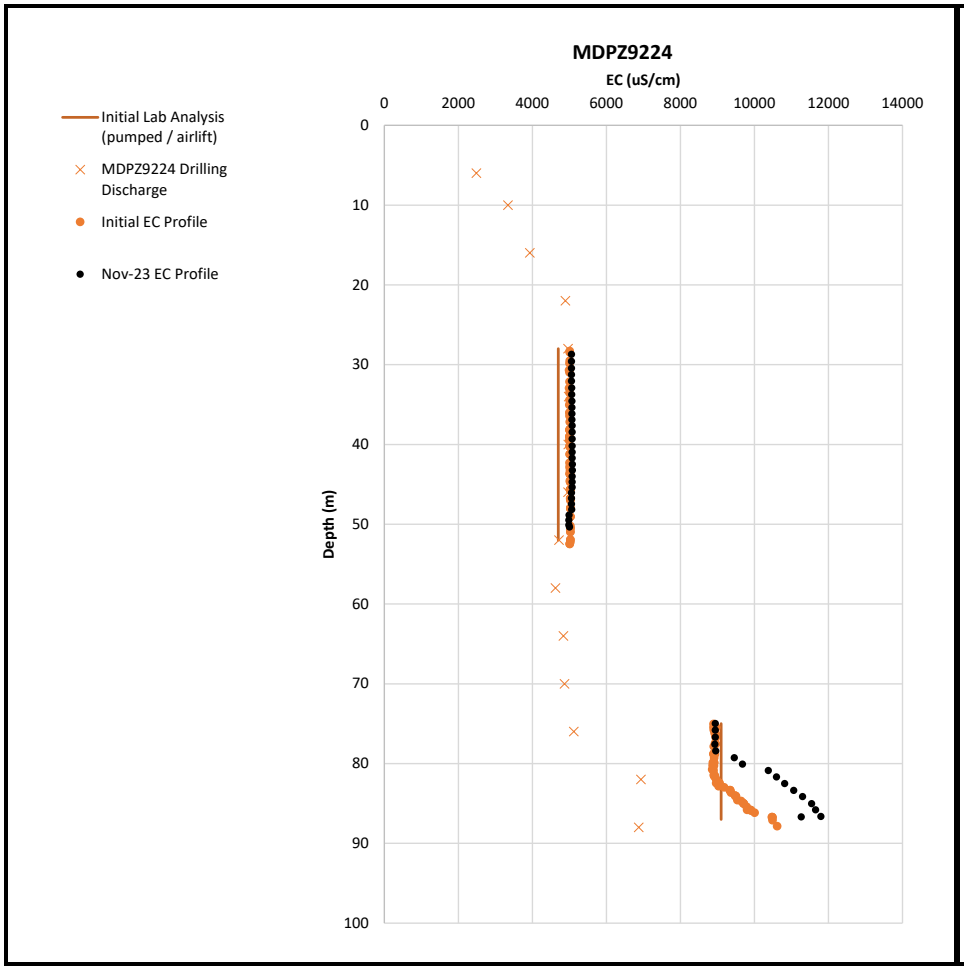

MDPZ9219
EC (uS/cm)
0
5000
10000
15000
20000
25000
Depth (m)
0
20
40
60
80
100
120
Initial Lab Analysis (pumped/airlift)
Initial EC Profile
Drilling Discharge
Dec-21 EC Profile
July-22 EC Profile
Oct-22 EC Profile
May-23 EC Profile
Nov-23 EC Profile
Dec-21 Hydrasleeve Lab Analysis
Jul-22 Hydrasleeve Lab Analysis
Oct-22 Hydrasleeve Lab Analysis
May-23 Hydrasleeve Lab Analysis
Nov-23 Hydrasleeve Lab Analysis

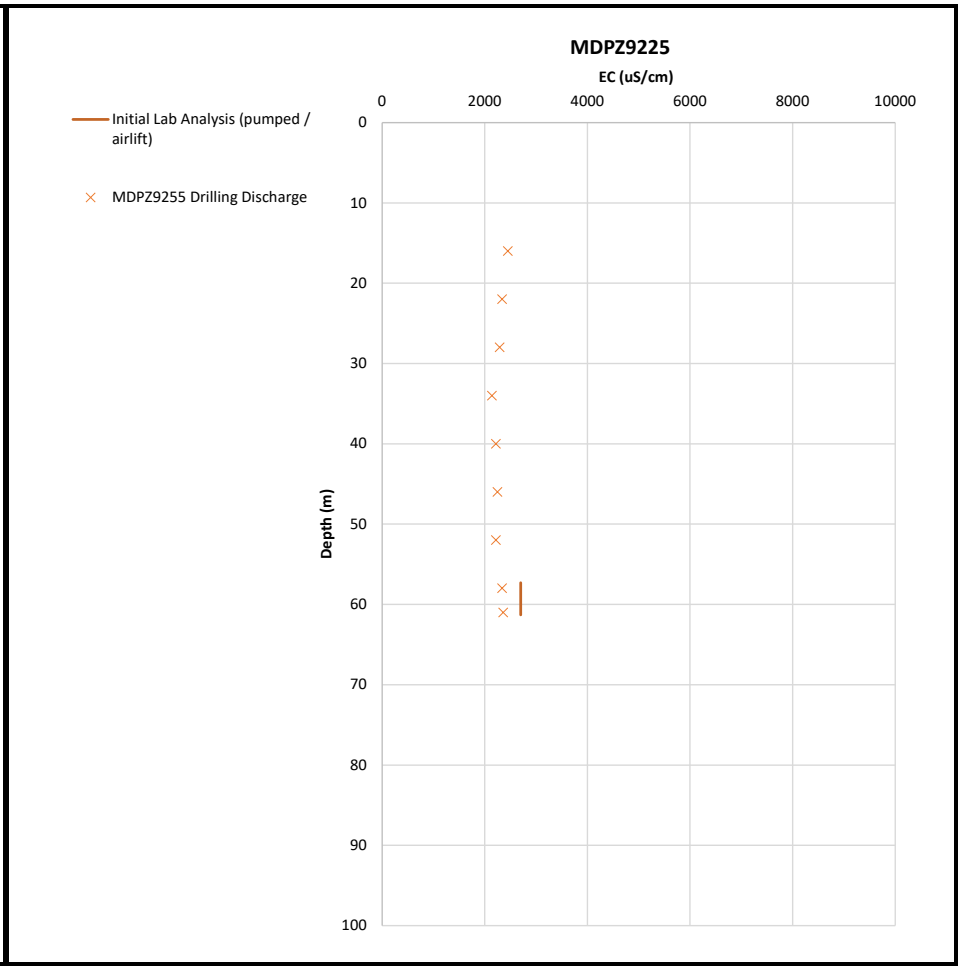

MDPZ9220
EC (uS/cm)
0
5000
10000
15000
20000
25000
Depth (m)
0
10
20
30
40
50
60
70
80
90
100
Initial Lab Analysis (pumped/airlift)
Initial EC Profile
Drilling Discharge
Dec-21 EC Profile
July-22 EC Profile
Oct-22 EC Profile
May-23 EC Profile
Nov-23 EC Profile
Dec-21 Hydrasleeve Lab Analysis
Jul-22 Hydrasleeve Lab Analysis
Oct-22 Hydrasleeve Lab Analysis
May-23 Hydrasleeve Lab Analysis
Nov-23 Hydrasleeve Lab Analysis


MDPZ9221
EC (uS/cm)
0
5000
10000
15000
20000
25000
Depth (m)
0
10
20
30
40
50
60
70
80
90
100
Initial Lab Analysis (pumped/airlift)
Initial EC Profile
Drilling Discharge
Dec-21 EC Profile
July-22 EC Profile
Oct-22 EC Profile
May-23 EC Profile
Nov-23 EC Profile
Dec-21 Hydrasleeve Lab Analysis
Jul-22 Hydrasleeve Lab Analysis
Oct-22 Hydrasleeve Lab Analysis
May-23 Hydrasleeve Lab Analysis
Nov-23 Hydrasleeve Lab Analysis


MDPZ9222
EC (uS/cm)
0
5000
10000
15000
20000
25000
Depth (m)
0
10
20
30
40
50
60
70
80
90
100
110
120
Initial Lab Analysis (pumped / airlift)
Initial EC Profile
MDPZ9222 Drilling Discharge
Nov-23 EC Profile
Nov-23 Hydrasleeve Lab Analysis


MDPZ9223
EC (uS/cm)
0
5000
10000
15000
20000
25000
Depth (m)
0
10
20
30
40
50
60
70
80
90
100
Initial Lab Analysis (pumped / airlift)
Initial EC Profile
MDPZ9223 Drilling Discharge
Nov-23 EC Profile
Nov-23 Hydrasleeve Lab Analysis


MDPZ9224
EC (uS/cm)
0
2000
4000
6000
8000
10000
12000
14000
Depth (m)
0
10
20
30
40
50
60
70
80
90
100
Initial Lab Analysis (pumped / airlift)
MDPZ9224 Drilling Discharge
Initial EC Profile
Nov-23 EC Profile


MDPZ9225
EC (uS/cm)
0
2000
4000
6000
8000
10000
Depth (m)
0
10
20
30
40
50
60
70
80
90
100
Initial Lab Analysis (pumped / airlift)
MDPZ9255 Drilling Discharge

APPENDIX I
CURRENT LOGGER & PASSIVE SAMPLER INSTALLATIONS

Bore Names	Easting MGA94_50	Northing MGA95_50	Ground Elevation (mAHD)	Tenement /Area	Logger type	Screened Interval (mbgl)[#]	Logger installation depth	Hydrosleeve Installation Depth (mbgl)		Static Water Level (SWL)		
								1st	2nd	Date	SWL (mbtoc)	SWL (mRL)
MDPZ7449A	655656	7551785	405.33	Mulga East	Level	52-82	50	65	-	01/12/21	5.00	400.93
MDPZ7449B	655657	7551795	405.44	Mulga East	Level	11-47	20	25	-	01/12/21	5.26	400.73
MDPZ7449C	655657	7551805	405.40	Mulga East	-	4-11	-	9	-	01/12/21	5.30	400.68
MDPZ7450A	652213	7552518	406.20	Mulga East	-	48-102	-	98	-	01/12/21	6.41	400.45
MDPZ7450B	652203	7552512	406.11	Mulga East	-	22-42	-	35	-	01/12/21	6.30	400.39
MDPZ7450C	652198	7552504	406.12	Mulga East	-	10-22	-	20	-	01/12/21	6.35	400.42
MDPZ7451A	651328	7550565	403.94	Mulga East	Level	94-120	40	105	-	01/12/21	5.14	399.32
MDPZ7451B	651335	7550574	403.99	Mulga East	Level	52-62	40	60	-	01/12/21	5.10	399.48
MDPZ7451C	651344	7550577	403.99	Mulga East	Level	14-44	16	20	-	01/12/21	4.77	399.77
MDPZ7452A	651327	7545806	403.78	Malay Well	Level	53-72	40	70	-	01/12/21	4.36	400.09
MDPZ7452B	651336	7545806	403.78	Malay Well	-	32.5-51.5	-	45	-	01/12/21	4.45	399.90
MDPZ7452C	651346	7545807	403.82	Malay Well	Aqua	8-32	15	20	-	01/12/21	4.58	399.86
MDPZ7453A	651180	7549447	404.88	Mulga East	Level	52.5-72.5	40	65	-	01/12/21	6.19	399.25
MDPZ7453B	651189	7549447	404.82	Mulga East	Level	30-48	36	40	-	01/12/21	6.15	399.27
MDPZ7453C	651199	7549448	404.72	Mulga East	Aqua	9-17	12	10	-	01/12/21	6.04	399.26
MDPZ7454	657054	7555456	435.90	Mulga East	Level	16-48	45	50	-	01/12/21	26.54	409.95
MDPZ7455	661108	7554688	448.12	Mulga East	Level	14-60	45	50	-	01/12/21	31.96	416.75
MDPZ7456A	665851	7547906	410.11	Mulga East	-	62-120	-	105	-	01/12/21	8.48	402.19
MDPZ7456B	665865	7547918	410.10	Mulga East	Level	46-62	50	55	-	01/12/21	5.59	405.18
MDPZ7456C	665858	7547912	410.10	Mulga East	Aqua	6-41	15	20	-	01/12/21	8.60	402.12
MDPZ7457A	656707	7548168	404.48	Mulga East	Level	76-100	50	90	-	01/12/21	4.92	400.10
MDPZ7457B	656716	7548167	404.53	Mulga East	Level	41-59	50	45	-	01/12/21	4.79	400.28
MDPZ7457C	656726	7548166	404.55	Mulga East	Aqua	19-35	25	28	-	01/12/21	4.80	400.34
MDPZ7458A	656646	7546146	404.15	Malay Well	Level	54-71	50	68	-	01/12/21	4.43	400.30
MDPZ7458B	656655	7546145	404.25	Malay Well	-	45-52	-	50	-	01/12/21	4.48	400.33
MDPZ7458C	656665	7546145	404.19	Malay Well	Aqua	5-41	15	8	-	01/12/21	4.56	400.32
MDPZ7459	650262	7554484	410.14	Mulga East	Level	5-28	15	20	-	01/12/21	11.07	399.66
MDPZ7460A	663201	7547990	406.19	Mulga East	Level	70-112	40	85	-	01/12/21	5.08	401.58
MDPZ7460B	663194	7547982	406.12	Mulga East	Level	45.4-51.4	48	49	-	01/12/21	5.28	401.39
MDPZ7460C	663189	7547976	406.17	Mulga East	Level	17.3-29.3	22	25	-	01/12/21	5.35	401.39
MDPZ7461	656011	7542996	405.27	Malay Well	Level	5.2-119.2	50	20	-	01/12/21	5.10	400.64
MDPZ7462A*	644800	7548090	403.91	Malay Well	Level	63-120	85	115	-	03/05/20	4.83	399.58
MDPZ7462B*	644800	7548100	403.99	Malay Well	Level	39.5-58.5	50	55	-	03/05/20	4.92	399.54
MDPZ7462C*	644799	7548110	403.96	Malay Well	Aqua	21-35	28	30	-	03/05/20	4.92	399.58
MDPZ7463	642863	7553587	403.98	Malay Well	Level	10.5-85.5	30	15	80	01/12/21	5.50	398.87
MDPZ7464	649944	7552426	405.78	Mulga East	Level	6-88	30	15	80	01/12/21	6.56	399.62
MDPZ7465	670002	7547875	418.35	Mulga East	Level	87.5-111.5	50	90	-	01/12/21	15.75	403.11
MDPZ7466	671336	7550528	438.39	Mulga East	Level	34.8-64.8	53	40	60	01/12/21	34.90	404.05
MDPZ7467	667655	7552969	449.30	Mulga East	Level	34-64	59	50	62	01/12/21	43.51	406.27
MDPZ7468A	647192	7551561	403.14	Malay Well	Level	68-89	44	85	-	01/12/21	4.83	398.77
MDPZ7468B	647196	7551570	403.14	Malay Well	-	56-62	-	60	-	01/12/21	4.89	398.79
MDPZ7468C	647199	7551579	403.20	Malay Well	Aqua	21.3-51	25	30	-	01/12/21	4.92	398.82
MDPZ7469A	657312	7550018	403.77	Mulga East	Level	93-101	50	100	-	01/12/21	4.00	400.31
MDPZ7469B	657308	7550027	403.76	Mulga East	-	64-82	-	75	-	01/12/21	3.44	400.81
MDPZ7469C	657303	7550035	403.76	Mulga East	Level	10.5-52.5	30	35	-	01/12/21	3.47	400.77
MDPZ7470A	661397	7546377	404.79	Malay Well	Level	74-104	40	90	-	01/12/21	4.58	401.06
MDPZ7470B	661388	7546376	404.82	Malay Well	Level	29.1-49.1	40	45	-	01/12/21	4.71	401.11

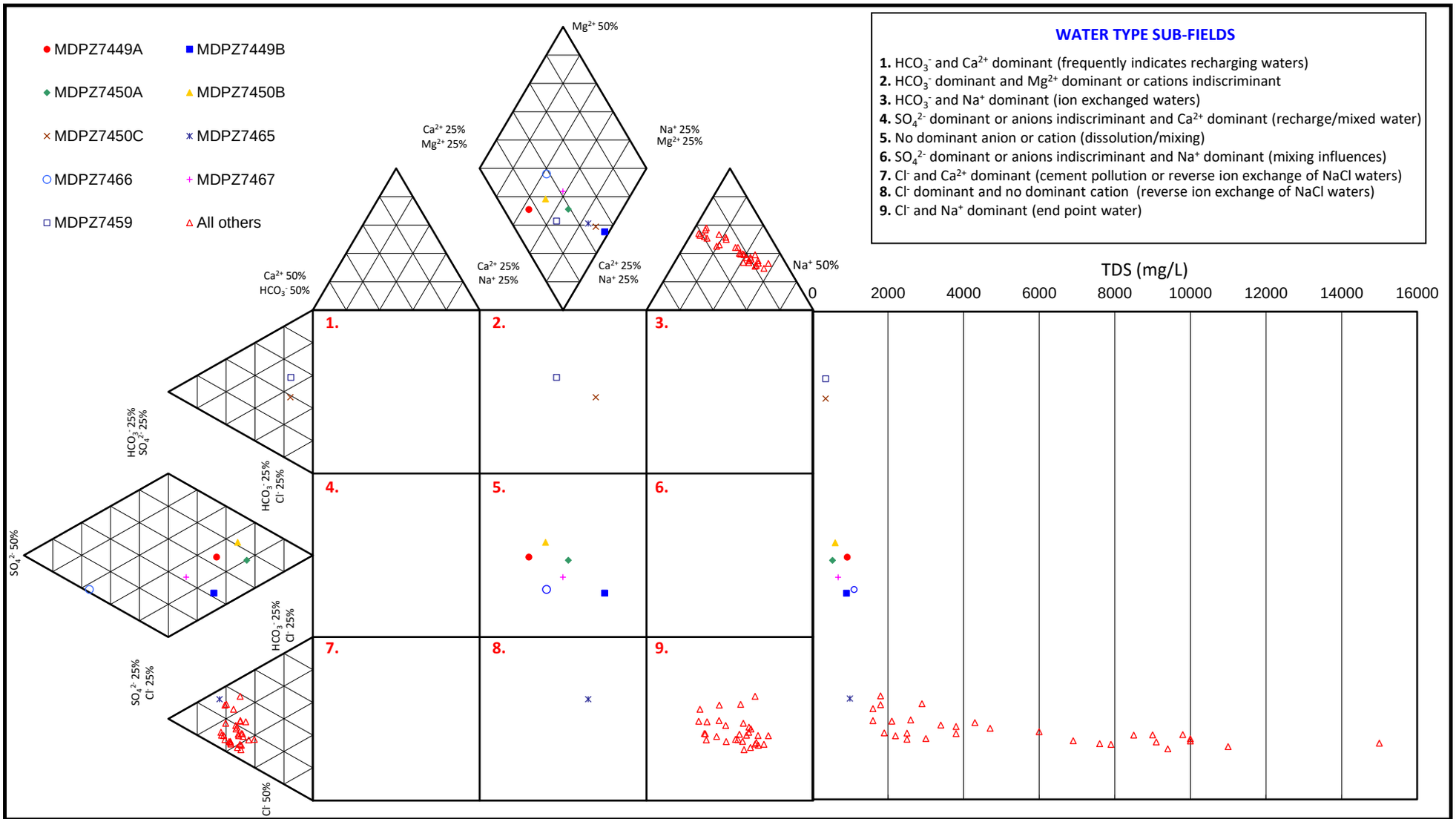
Bore Names	Easting MGA94_50	Northing MGA95_50	Ground Elevation (mAHD)	Tenement /Area	Logger type	Screened Interval (mbgl)[#]	Logger installation depth	Hydrosleeve Installation Depth (mbgl)		Static Water Level (SWL)		
								1st	2nd	Date	SWL (mbtoc)	SWL (mRL)
MDPZ7470C	661379	7546376	404.74	Malay Well	Aqua	11-23	18	20	-	01/12/21	4.70	401.10
MDPZ7471A	646671	7549390	402.70	Malay Well	Level	68-78	40	72	-	01/12/21	4.39	399.21
MDPZ7471B	646661	7549391	402.68	Malay Well	Level	30-60	48	55	-	01/12/21	4.61	399.17
MDPZ7471C	646681	7549389	402.64	Malay Well	Aqua	11-21	18	15	-	01/12/21	4.68	398.89
MDPZ0494	655469	7553694	412.03	Mulga East	-	58	-	-	-	01/12/21	11.64	400.80
MDPZ0574	655630	7552222	405.34	Mulga East	-	52	-	-	-	01/12/21	blocked	-
MDPZ0540	656947	7553007	411.55	Mulga East	-	70	-	-	-	01/12/21	11.50	400.25
MDPZ0551	656669	7554009	416.70	Mulga East	-	58	-	-	-	01/12/21	blocked	-
MDPZ0704	659649	7549220	405.11	Mulga East	Level 400	88	30	-	-	01/12/21	4.20	400.91
MDPZ0757	669994	7547876	418.21	Mulga East	Level 400	76	30	-	-	01/12/21	15.39	403.07
MDPZ0818	663226	7550822	418.98	Mulga East	Rugged	64	30	-	-	01/12/21	17.38	401.90
MDPZ9205	672010	7548259	418.50	Mulga East	Level	16-70	40	35	-	01/12/21	17.65	401.38
MDPZ9211	656000	7545396	403.88	Malay Well	Level	34-130	30	48	-	15/12/21	3.94	400.34
MDPZ9212D	654400	7546689	405.17	Malay Well	Level	100.5-118.5	30	105	-	15/12/21	5.61	400.01
MDPZ9212S	654386	7546688	404.95	Malay Well	Aqua	5-59	10	20	-	15/12/21	5.28	400.11
MDPZ9213	649610	7544612	404.53	Malay Well	Level	18.5-120.5	30	40	-	15/12/21	5.04	399.94
MDPZ9214	647989	7547414	403.02	Malay Well	Aqua	3.7-123.7	10	-	-	15/12/21	4.10	399.37
MDPZ9215D	643992	7550206	403.21	Malay Well	Level	70-130	30	80	-	15/12/21	4.73	398.86
MDPZ9215S	643992	7550192	403.14	Malay Well	Aqua	5-59	10	20	-	15/12/21	4.54	399.07
MDPZ9216	643199	7551012	403.24	Malay Well	Level	83.5-119.5	30	90	-	15/12/21	5.24	398.42
MDPZ9217	632854	7556252	402.09	Mulga West	Aqua	5-89	12	30	-	13/12/21	4.76	397.75
MDPZ9218	622035	7555800	398.85	Mulga West	Aqua	8-92	12	30	-	13/12/21	3.43	395.82
MDPZ9219	618440	7555798	396.82	Mulga West	Aqua	10-112	12	30	-	13/12/21	3.70	393.58
MDPZ9220	610046	7558820	394.98	Mulga West	Level	10.5-94.5	15	30	-	13/12/21	6.32	389.03
MDPZ9221	609649	7560972	389.85	Mulga West	Aqua	11-83	12	30	-	14/12/21	2.50	387.35
MDPZ9222S	643187	7551797	tbc	Malay Well	Aqua	10-40	14	15	-	12/11/23	5.48	tbc
MDPZ9223S	648838	7546180	tbc	Malay Well	Level	9-30	14	15	-	13/11/23	5.66	tbc
MDPZ9223D	648835	7546202	tbc	Malay Well	-	68-92	-	75	-	13/11/23	5.67	tbc
MDPZ9224S	647970	7547389	tbc	Malay Well	-	28-52	-	40	-	13/11/23	4.55	tbc
MDPZ9224D	647965	7547379	tbc	Malay Well	-	28-52	-	78	-	13/11/23	5.60	tbc
MDPZ9225	649571	7544628	tbc	Malay Well	Level	57.3-61.3	14	-	-	13/11/23	5.52	tbc
MD5382	632061	7559002	408.70	Mulga West	-	10-82	-	-	-	13/12/21	11.41	397.77
~~MD5455~~	~~627439~~	~~7559605~~	~~412.55~~	~~Mulga West~~	~~-~~	~~18-72~~	~~-~~	~~45~~	~~68~~	07/08/21	15.78	396.77
MD5461	626244	7559392	412.56	Mulga West	Level	0-78	50	65	-	13/12/21	16.94	396.20
~~MD6605~~	~~630847~~	~~7559397~~	~~412.17~~	~~Mulga West~~	~~-~~	~~10-106~~	~~-~~	~~85~~	~~55~~	13/12/21	14.84	397.76

Notes

End of hole quoted where screened interval is unknown (for historic bores)

* Access to these bores is now restricted. Original Solinst loggers at these bores replaced in Sept 2024

APPENDIX J
EXPANDED DUROV DIAGRAMS &
WATER TYPES VERSUS TIME SUMMARY



Mulga East Monitoring Bores Sampled at Installation
Expanded Durov Diagram

Date: 19/02/20

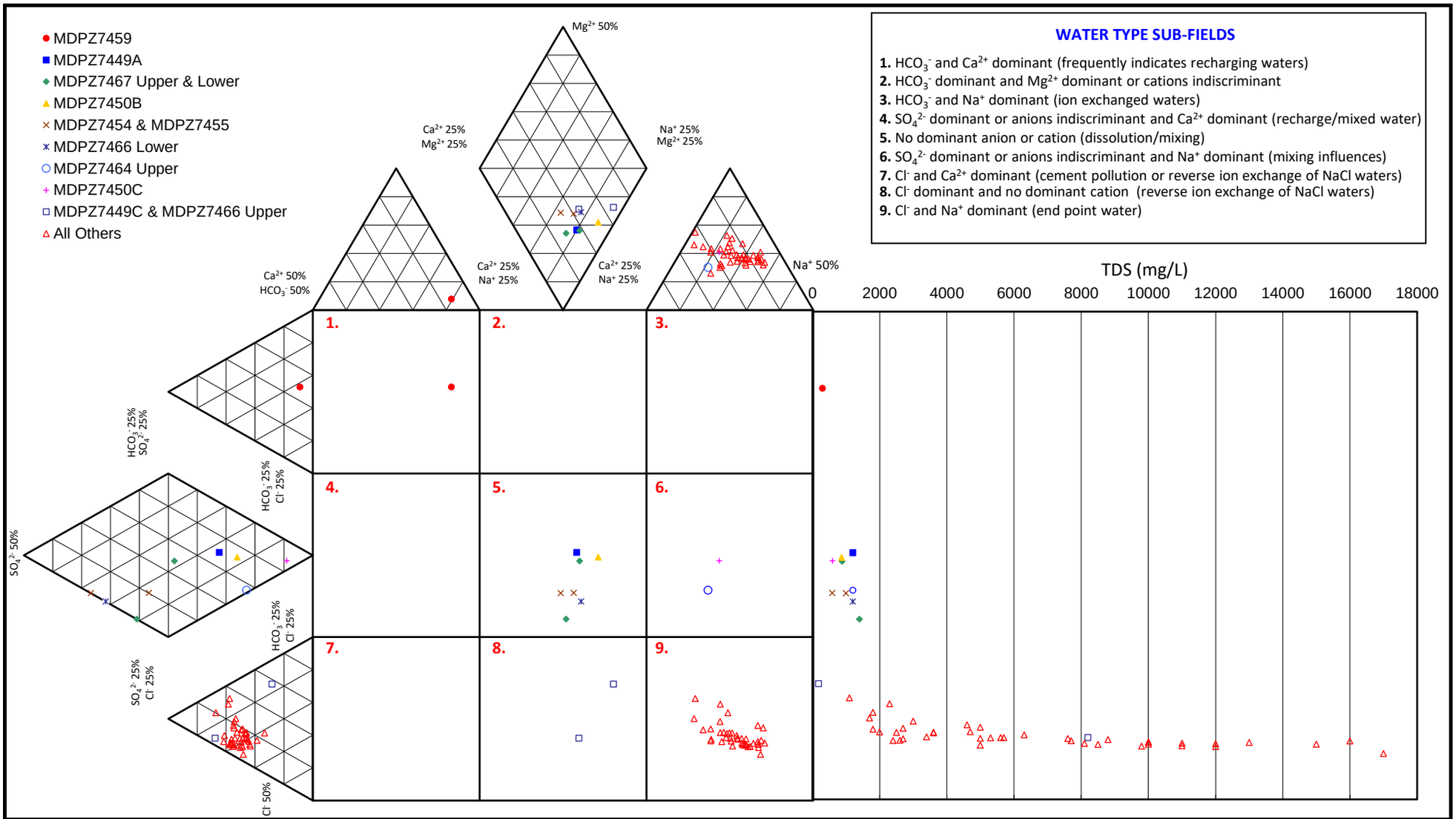
F:\171\2.TECH\Water Samples\[Mulga_HYDROCHEM_15-7-19_rev.xlsm]EXPANDED DUROV (1)

Project: Mulga East

Project No: 171C

Description:

Client: HPPL



WATER TYPE SUB-FIELDS

1. HCO_3^- and Ca^{2+} dominant (frequently indicates recharging waters)
2. HCO_3^- dominant and Mg^{2+} dominant or cations indiscriminant
3. HCO_3^- and Na^+ dominant (ion exchanged waters)
4. SO_4^{2-} dominant or anions indiscriminant and Ca^{2+} dominant (recharge/mixed water)
5. No dominant anion or cation (dissolution/mixing)
6. SO_4^{2-} dominant or anions indiscriminant and Na^+ dominant (mixing influences)
7. Cl^- and Ca^{2+} dominant (cement pollution or reverse ion exchange of NaCl waters)
8. Cl^- dominant and no dominant cation (reverse ion exchange of NaCl waters)
9. Cl^- and Na^+ dominant (end point water)

Mulga East Monitoring Bores Sampled Nov 2019
Expanded Durov Diagram

Date: 19/02/20

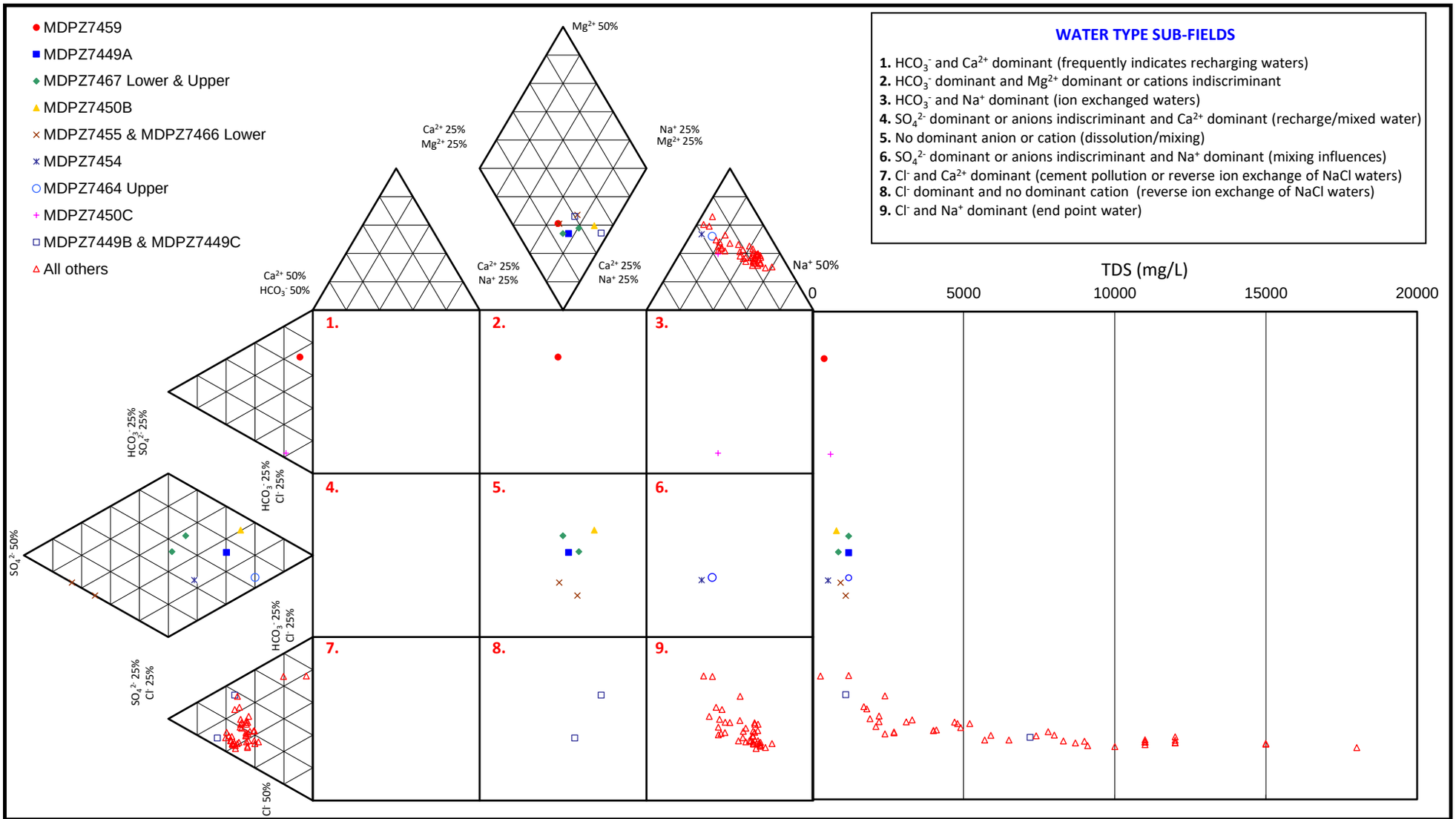
F:\171\2.TECH\Water Samples\[Mulga_HYDROCHEM_Nov 2019 Sampling.xlsm]Input Data

Project: Mulga East

Project No: 171C

Description:

Client: HPPL



WATER TYPE SUB-FIELDS

1. HCO_3^- and Ca^{2+} dominant (frequently indicates recharging waters)
2. HCO_3^- dominant and Mg^{2+} dominant or cations indiscriminant
3. HCO_3^- and Na^+ dominant (ion exchanged waters)
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5. No dominant anion or cation (dissolution/mixing)
6. SO_4^{2-} dominant or anions indiscriminant and Na^+ dominant (mixing influences)
7. Cl^- and Ca^{2+} dominant (cement pollution or reverse ion exchange of NaCl waters)
8. Cl^- dominant and no dominant cation (reverse ion exchange of NaCl waters)
9. Cl^- and Na^+ dominant (end point water)

Mulga East Monitoring Bores Sampled May 2020
Expanded Durov Diagram

Date: 09/06/20

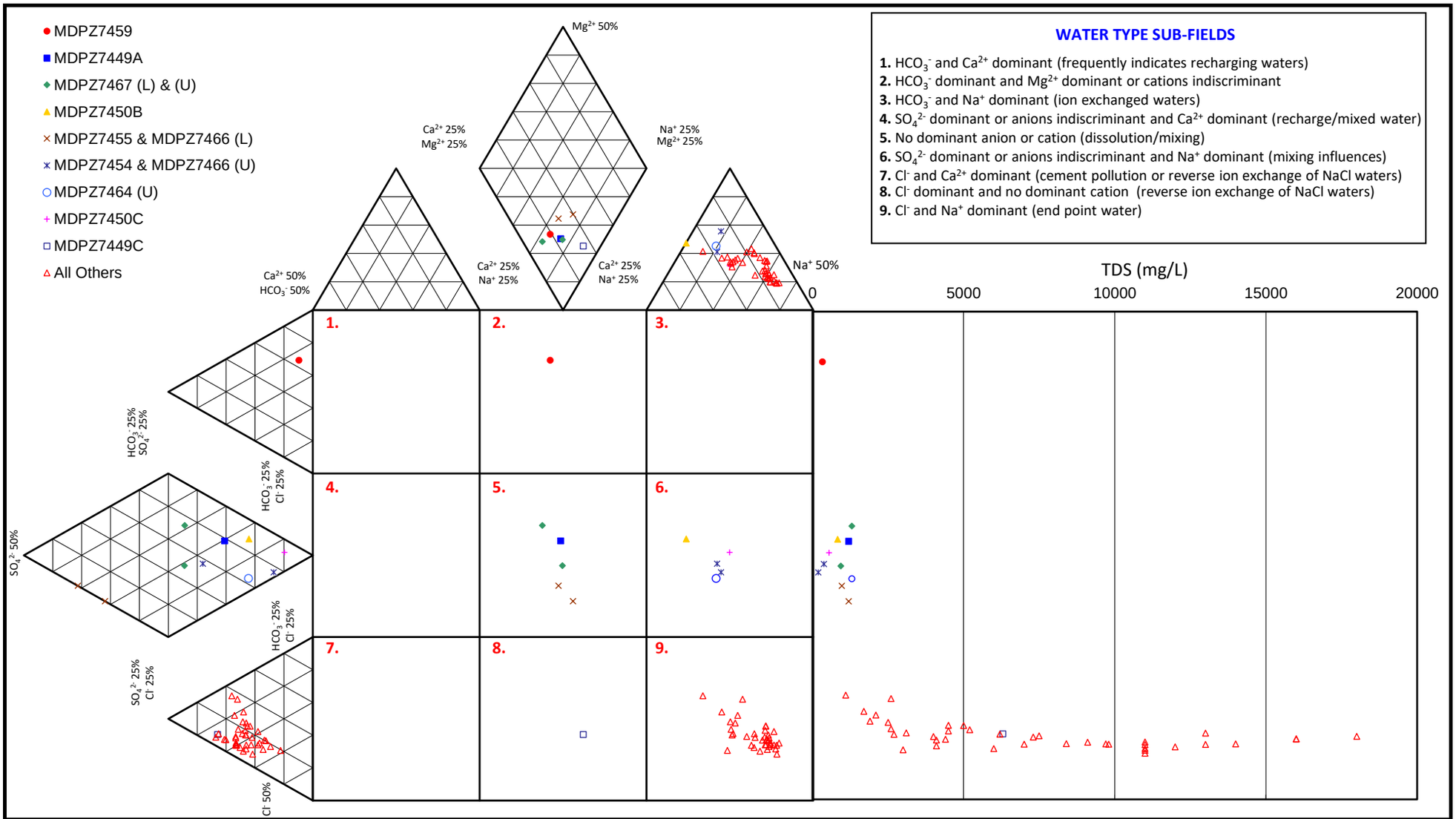
Project: Mulga East

Description:

Project No: 171C

Client: HPPL

F:\171\2.TECH\Water Samples\[Mulga_HYDROCHEM_May 2020 Sampling.xlsm]EXPANDED DUROV (1)

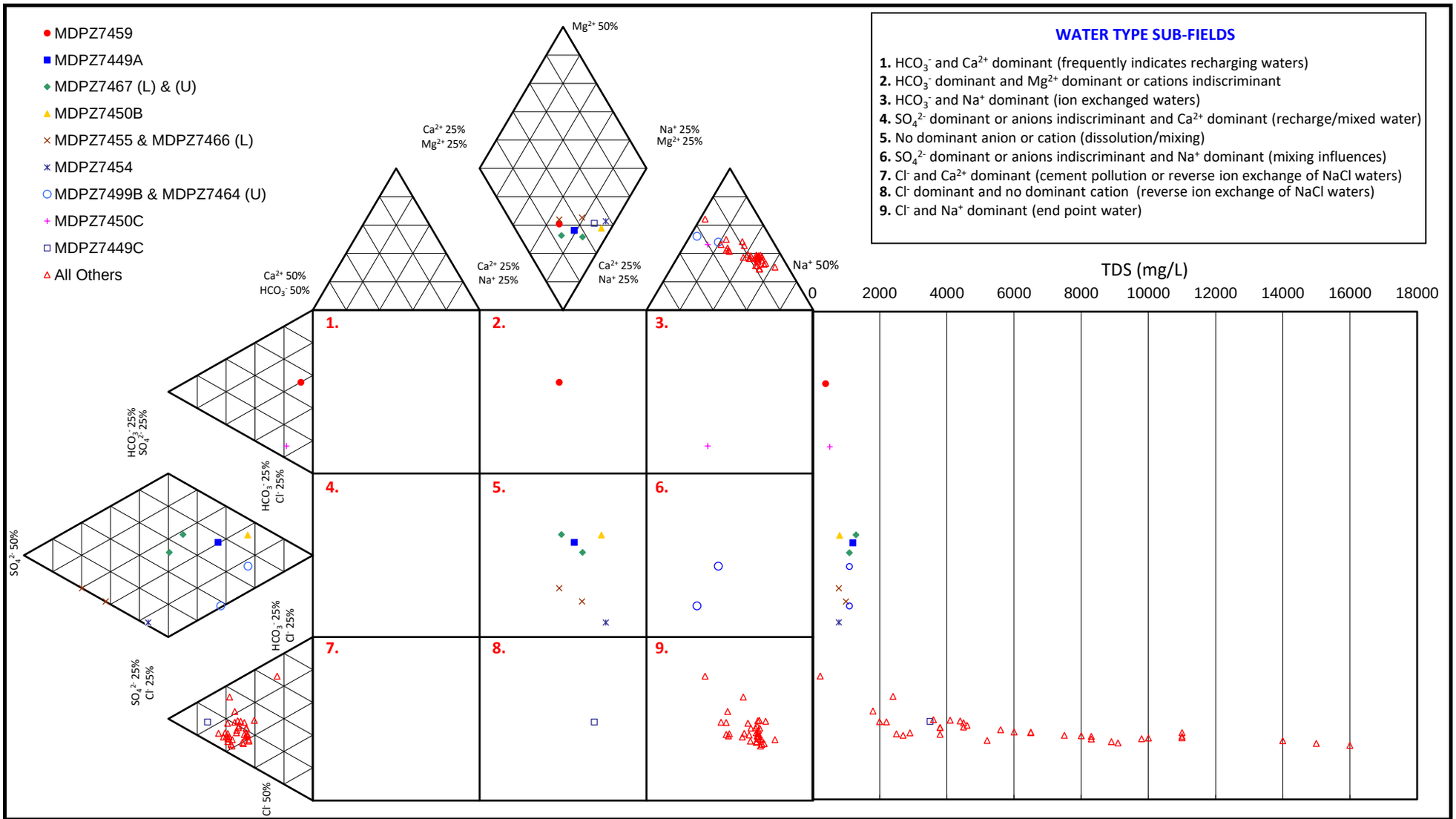


WATER TYPE SUB-FIELDS

1. HCO_3^- and Ca^{2+} dominant (frequently indicates recharging waters)
2. HCO_3^- dominant and Mg^{2+} dominant or cations indiscriminant
3. HCO_3^- and Na^+ dominant (ion exchanged waters)
4. SO_4^{2-} dominant or anions indiscriminant and Ca^{2+} dominant (recharge/mixed water)
5. No dominant anion or cation (dissolution/mixing)
6. SO_4^{2-} dominant or anions indiscriminant and Na^+ dominant (mixing influences)
7. Cl^- and Ca^{2+} dominant (cement pollution or reverse ion exchange of NaCl waters)
8. Cl^- dominant and no dominant cation (reverse ion exchange of NaCl waters)
9. Cl^- and Na^+ dominant (end point water)

Mulga East Baseline Monitoring Bores
Sampled March / August 2021
Expanded Durov Diagram

Date:	31/08/21	Project:	Mulga East	Description: Baseline Monitoring
F:\171\2.TECH\Water Samples\[Mulga_HYDROCHEM_Mar&Aug 2021 sampling.xlsm]EXPANDED DUROV (1)		Project No:	171J	Client: HPPL / Roy Hill



WATER TYPE SUB-FIELDS

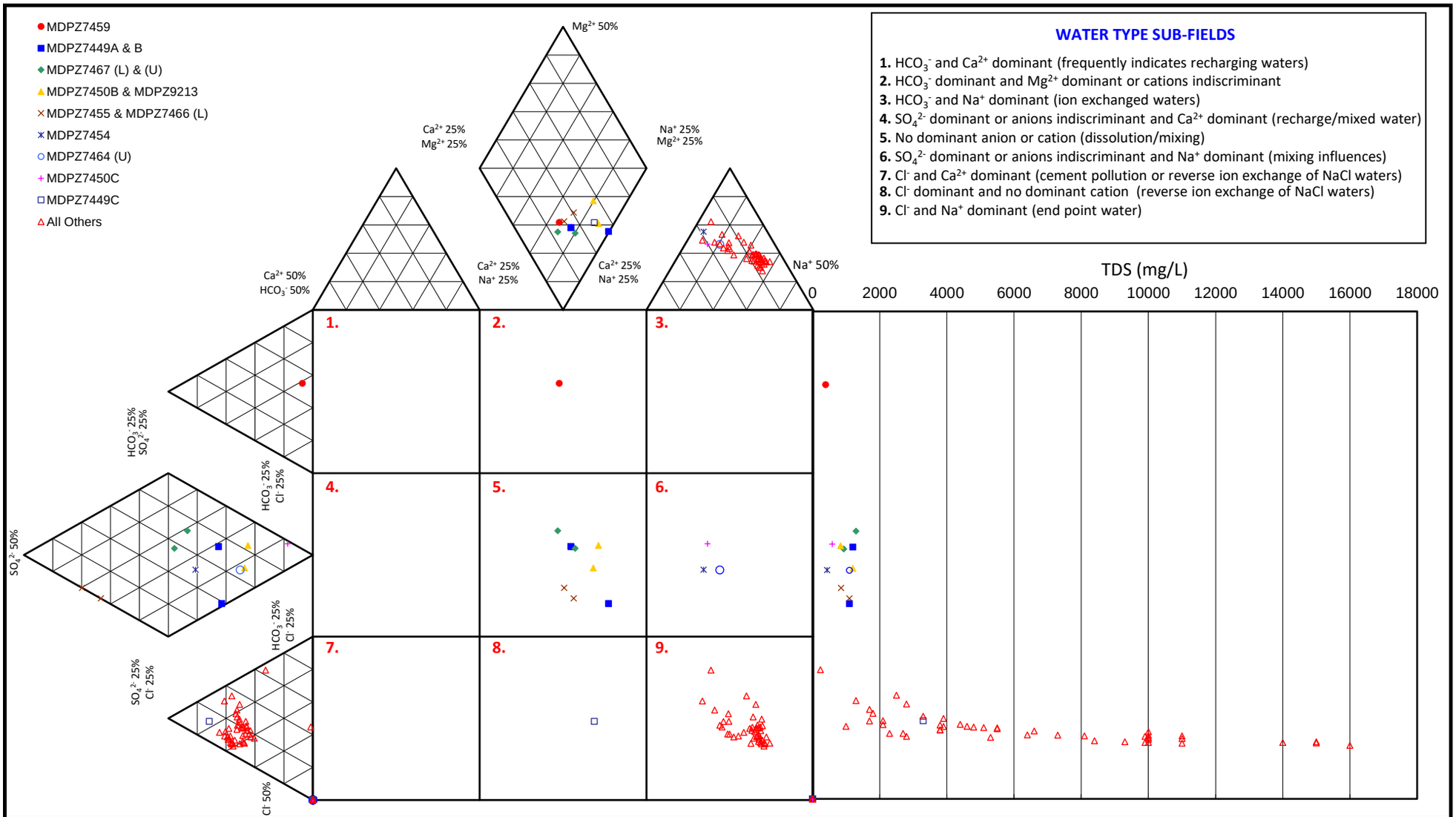
1. HCO_3^- and Ca^{2+} dominant (frequently indicates recharging waters)
2. HCO_3^- dominant and Mg^{2+} dominant or cations indiscriminant
3. HCO_3^- and Na^+ dominant (ion exchanged waters)
4. SO_4^{2-} dominant or anions indiscriminant and Ca^{2+} dominant (recharge/mixed water)
5. No dominant anion or cation (dissolution/mixing)
6. SO_4^{2-} dominant or anions indiscriminant and Na^+ dominant (mixing influences)
7. Cl^- and Ca^{2+} dominant (cement pollution or reverse ion exchange of NaCl waters)
8. Cl^- dominant and no dominant cation (reverse ion exchange of NaCl waters)
9. Cl^- and Na^+ dominant (end point water)

AQ2

Mulga East Baseline Monitoring Bores
Sampled December 2021
Expanded Durov Diagram

Date:	10/01/22	Project:	Mulga East
		Project No:	171J
		Description:	Baseline Monitoring
		Client:	HPPL / Roy Hill

F:\171\2.TECH\Water Samples\[Mulga_HYDROCHEM_Dec 2021 sampling.xlsm]EXPANDED DUROV (1)

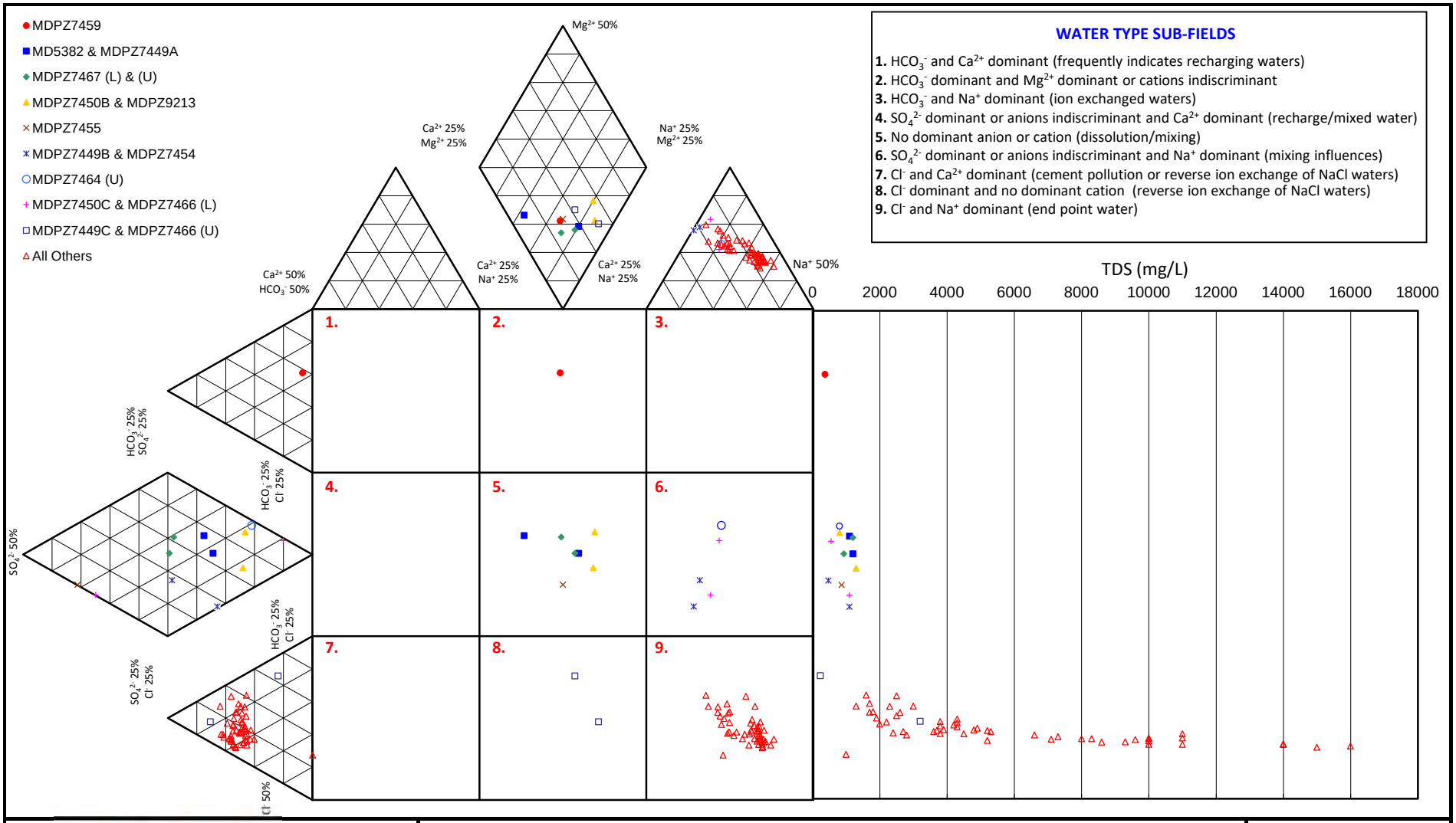


Mulga East & Malay Well Baseline Monitoring Bores
Sampled July 2022
Expanded Durov Diagram

Date: 16/09/2024

Samples\Mulga_HYDROCHEM_2022_CORRECT_Durov_Template\[Mulga_HYDROCHEM_Jul 2022 Sampling_17092024v2.xlsm]EXPANDED DUROV (1)

Project:	Mulga East & Malay Well	Description:	Baseline Monitoring
Project No:	171X	Client:	Hanroy



WATER TYPE SUB-FIELDS

1. HCO_3^- and Ca^{2+} dominant (frequently indicates recharging waters)
2. HCO_3^- dominant and Mg^{2+} dominant or cations indiscriminant
3. HCO_3^- and Na^+ dominant (ion exchanged waters)
4. SO_4^{2-} dominant or anions indiscriminant and Ca^{2+} dominant (recharge/mixed water)
5. No dominant anion or cation (dissolution/mixing)
6. SO_4^{2-} dominant or anions indiscriminant and Na^+ dominant (mixing influences)
7. Cl^- and Ca^{2+} dominant (cement pollution or reverse ion exchange of NaCl waters)
8. Cl^- dominant and no dominant cation (reverse ion exchange of NaCl waters)
9. Cl^- and Na^+ dominant (end point water)

Mulga East & Malay Well Baseline Monitoring Bores
October 2022
Expanded Durov Diagram

Date: 16/09/24

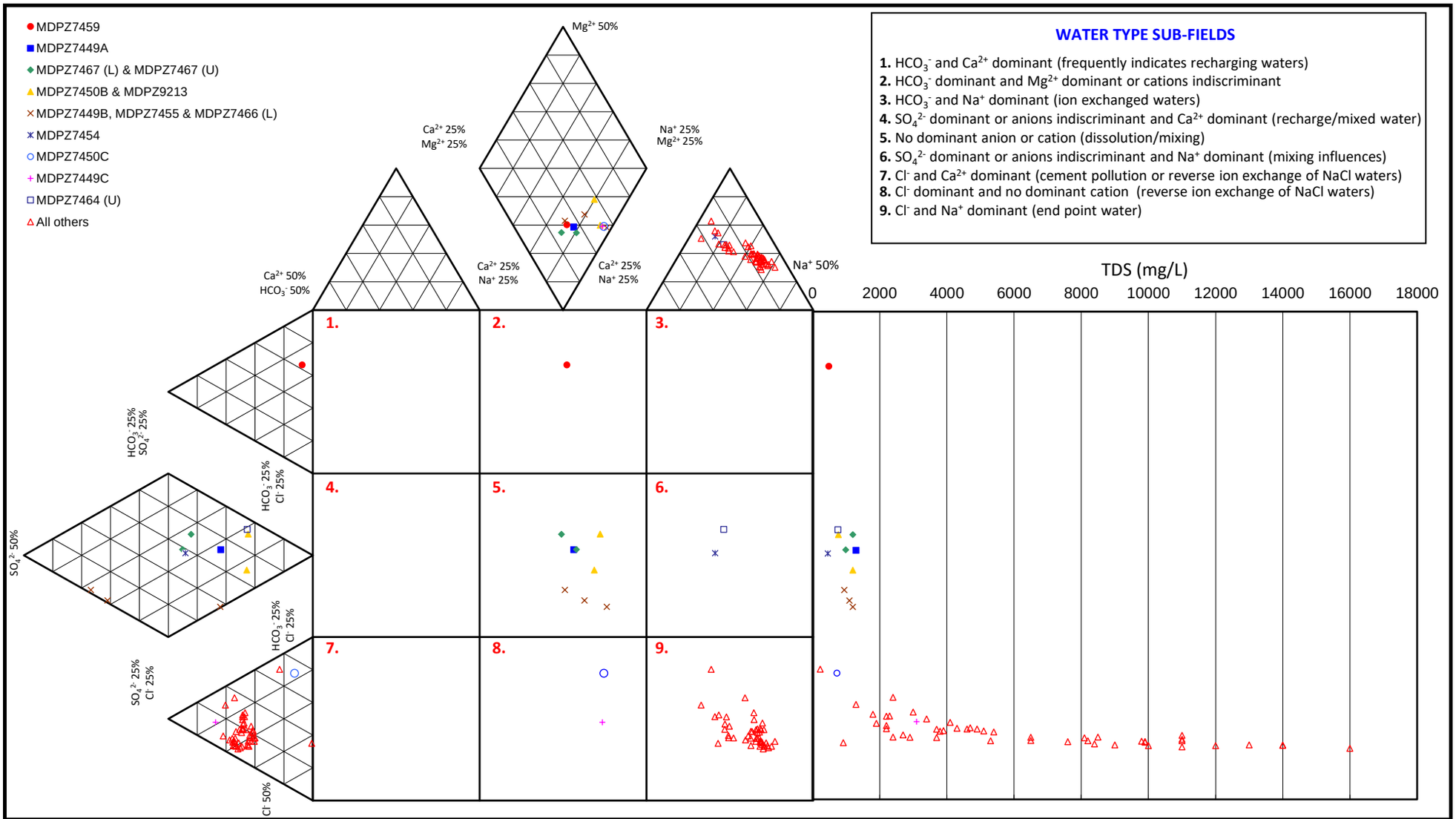
F:\171\2.TECH\Water Samples\Mulga_HYDROCHEM_2022_CORRECT_Durov_Template\[Mulga_HYDROCHEM_October_2022_02102022.xlsm]Input Data

Project: Mulga West, Mulga Downs

Project No: 171X

Description: Baseline Monitoring

Client: Hanroy

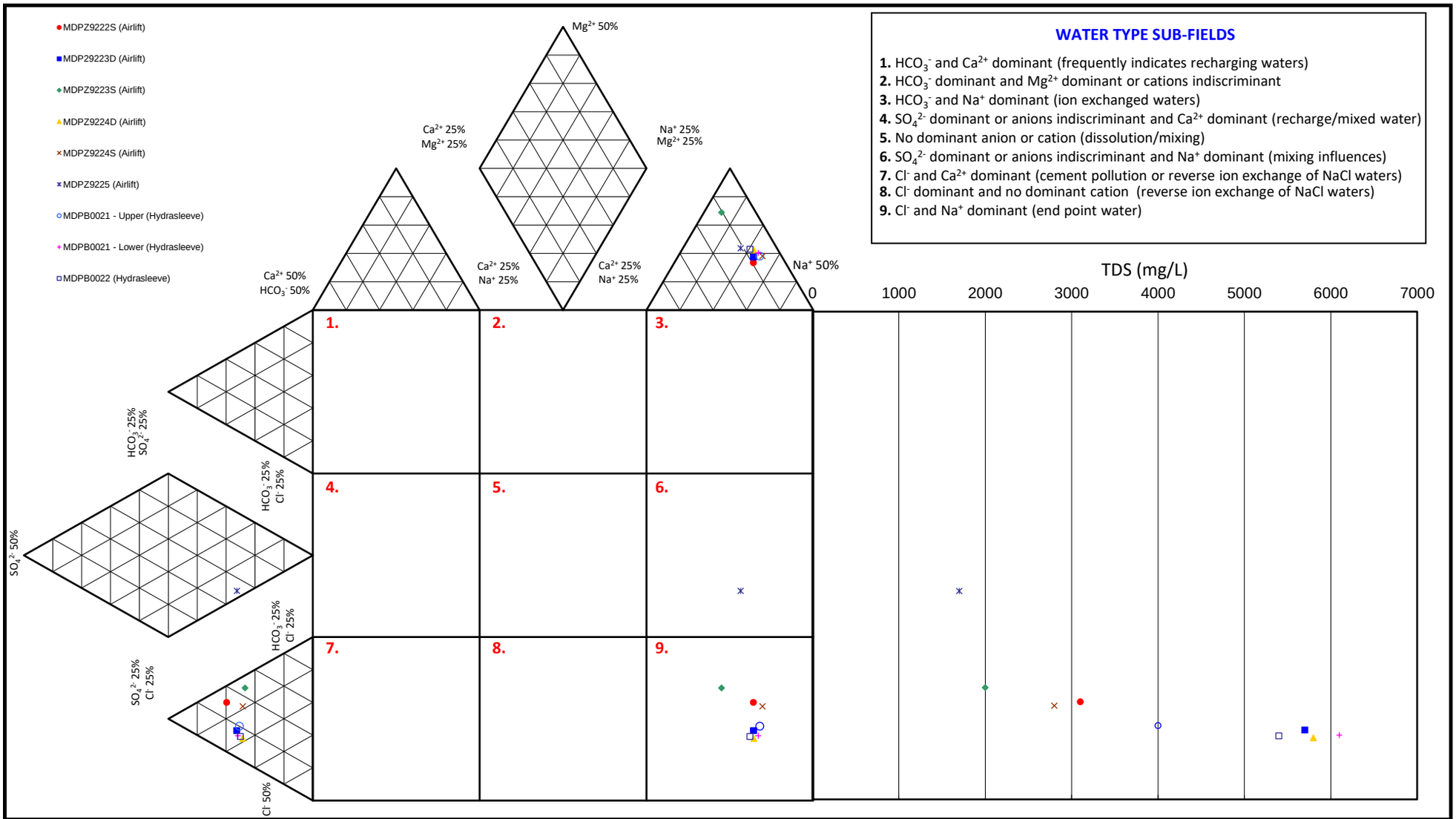


Mulga East and Malay Well Baseline Monitoring Bores
Sampled May 2023
Expanded Durov Diagram

Date: 16/09/2024

Samples\Mulga_HYDROCHEM_2023_CORRECT_Durov_Template\[Mulga_HYDROCHEM_May_2023_Sampling_16092024.xlsm]EXPANDED DUROV (1)

Project:	Mulga East & Malay Well	Description:	Baseline Monitoring
Project No:	171X	Client:	Hanroy



WATER TYPE SUB-FIELDS

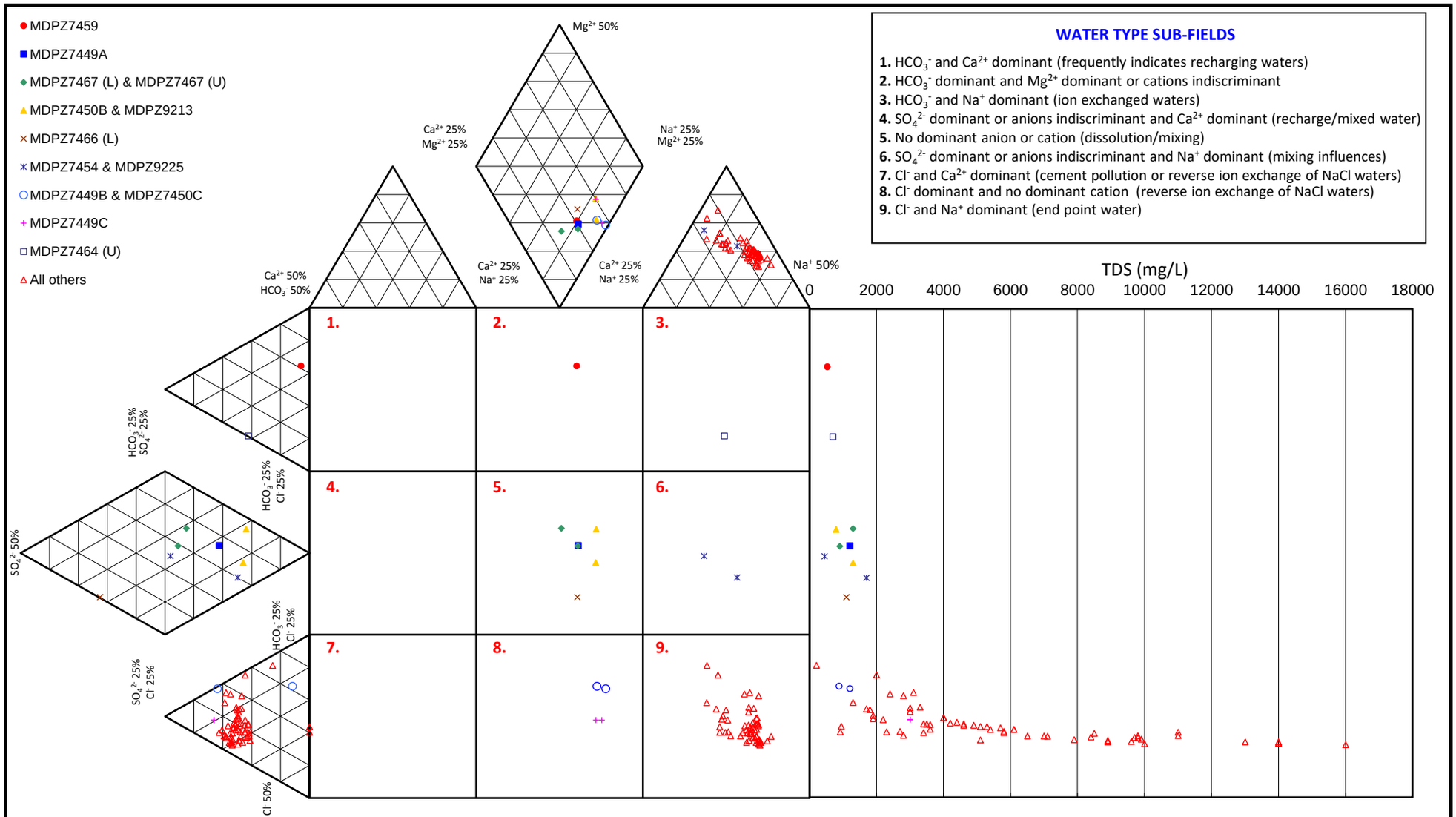
1. HCO_3^- and Ca^{2+} dominant (frequently indicates recharging waters)
2. HCO_3^- dominant and Mg^{2+} dominant or cations indiscriminant
3. HCO_3^- and Na^+ dominant (ion exchanged waters)
4. SO_4^{2-} dominant or anions indiscriminant and Ca^{2+} dominant (recharge/mixed water)
5. No dominant anion or cation (dissolution/mixing)
6. SO_4^{2-} dominant or anions indiscriminant and Na^+ dominant (mixing influences)
7. Cl^- and Ca^{2+} dominant (cement pollution or reverse ion exchange of NaCl waters)
8. Cl^- dominant and no dominant cation (reverse ion exchange of NaCl waters)
9. Cl^- and Na^+ dominant (end point water)

Malay Well 2023 Bore Installations
Expanded Durov Diagram

Date: 16/09/2024

Samples\Mulga_HYDROCHEM_2023_CORRECT_Durov_Template\[Mulga_HYDROCHEM_Malay_Well_Bore_Installations_2023_Sampling_01102024.xlsm]EXPANDED DUROV (1)

Project:	Malay Well	Description:	Baseline Monitoring
Project No:	171X	Client:	Hanroy



WATER TYPE SUB-FIELDS

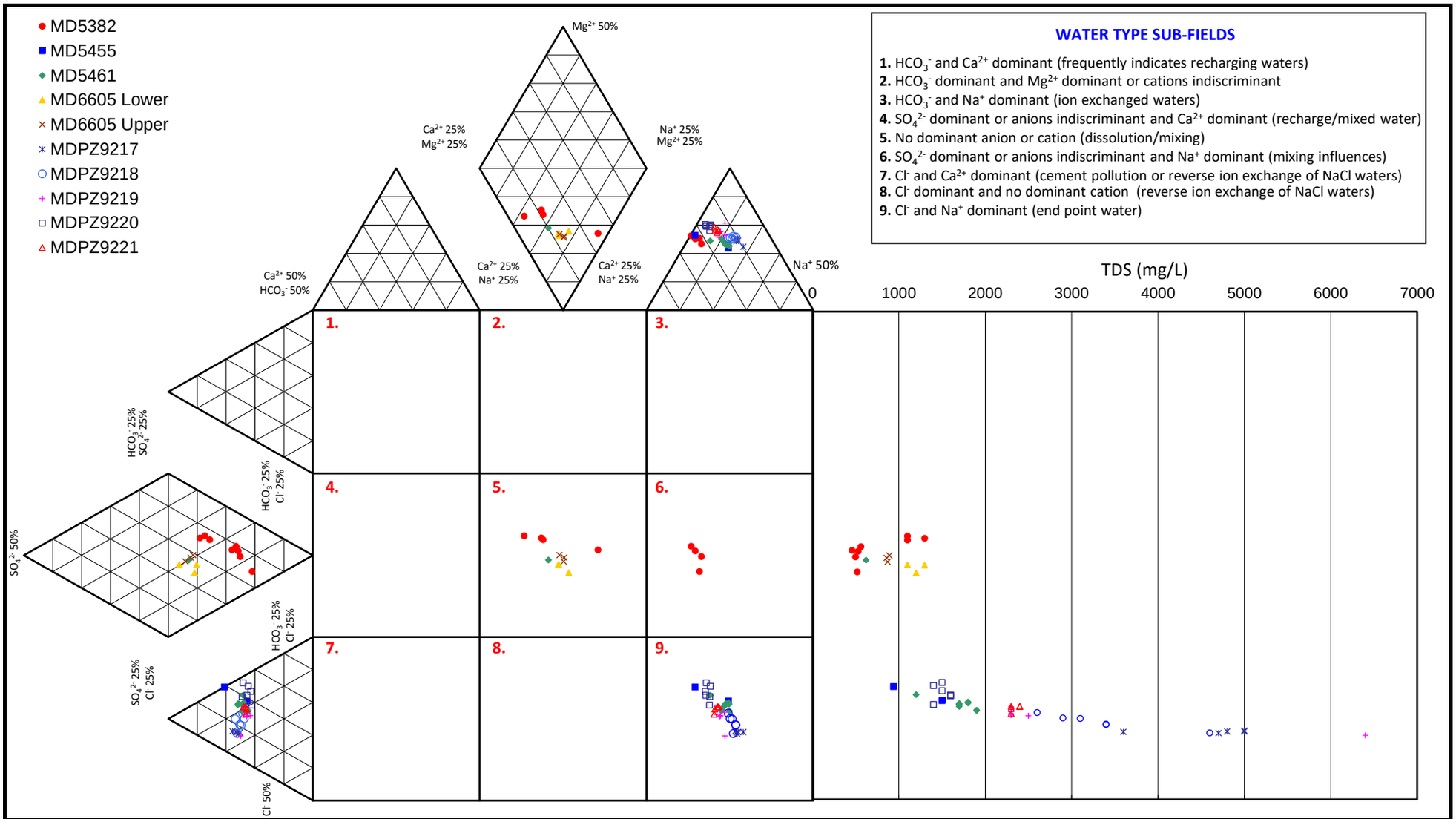
1. HCO_3^- and Ca^{2+} dominant (frequently indicates recharging waters)
2. HCO_3^- dominant and Mg^{2+} dominant or cations indiscriminant
3. HCO_3^- and Na^+ dominant (ion exchanged waters)
4. SO_4^{2-} dominant or anions indiscriminant and Ca^{2+} dominant (recharge/mixed water)
5. No dominant anion or cation (dissolution/mixing)
6. SO_4^{2-} dominant or anions indiscriminant and Na^+ dominant (mixing influences)
7. Cl^- and Ca^{2+} dominant (cement pollution or reverse ion exchange of NaCl waters)
8. Cl^- dominant and no dominant cation (reverse ion exchange of NaCl waters)
9. Cl^- and Na^+ dominant (end point water)

Mulga East and Malay Well Baseline Monitoring Bores
Sampled November 2023
Expanded Durov Diagram

Date: 16/09/2024

Samples\Mulga_HYDROCHEM_2023_CORRECT_Durov_Template\[Mulga_HYDROCHEM_Nov_2023_Sampling_01102024.xlsm]EXPANDED DUROV (1)

Project:	Mulga East & Malay Well	Description:	Baseline Monitoring
Project No:	171X	Client:	Hanroy



WATER TYPE SUB-FIELDS

1. HCO_3^- and Ca^{2+} dominant (frequently indicates recharging waters)
2. HCO_3^- dominant and Mg^{2+} dominant or cations indiscriminant
3. HCO_3^- and Na^+ dominant (ion exchanged waters)
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5. No dominant anion or cation (dissolution/mixing)
6. SO_4^{2-} dominant or anions indiscriminant and Na^+ dominant (mixing influences)
7. Cl^- and Ca^{2+} dominant (cement pollution or reverse ion exchange of NaCl waters)
8. Cl^- dominant and no dominant cation (reverse ion exchange of NaCl waters)
9. Cl^- and Na^+ dominant (end point water)

AQ2

Mulga West Baseline Monitoring
August 2019 to November 2023
Expanded Durov Diagram

Date: 16/09/24

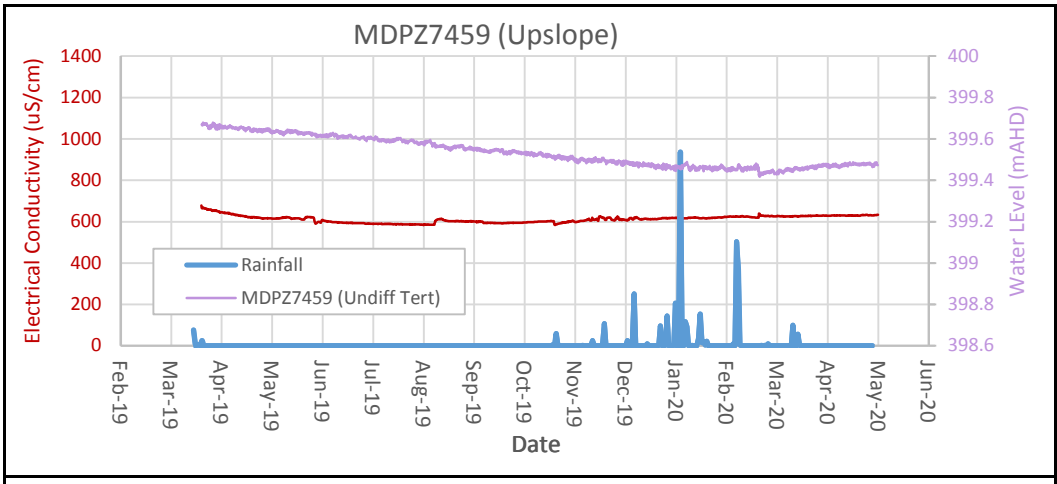
F:\1712.TECH\Water Samples\Mulga_HYDROCHEM_2023_CORRECT_Durov_Template\[Mulga_HYDROCHEM_Mulga West up to Nov 2023 Sampling_02102024.xlsm]EXPANDED DUROV (1)

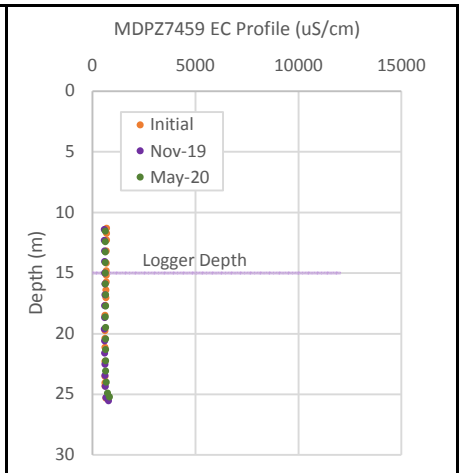
Project: Mulga West, Mulga Downs
Description: Baseline Monitoring
Project No: 171X
Client: Hanroy

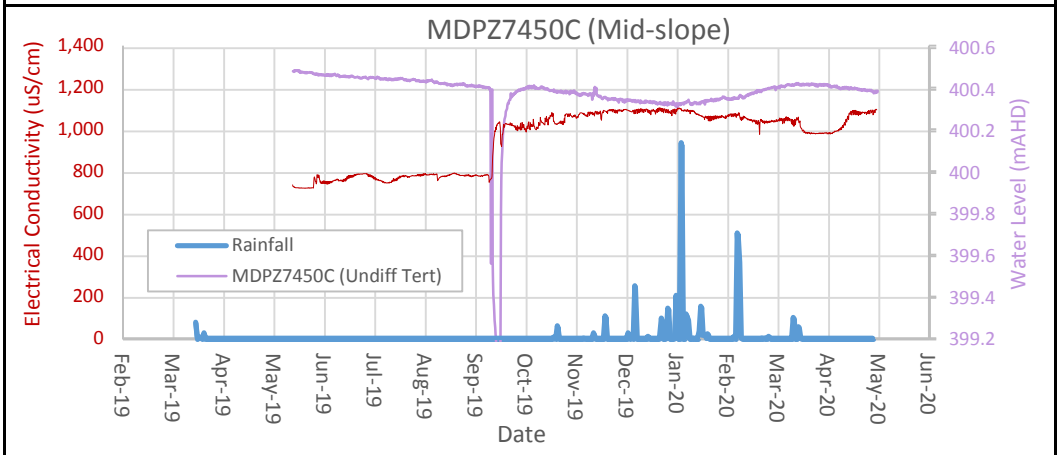
Mulga Downs Summary of Water Types Over Time

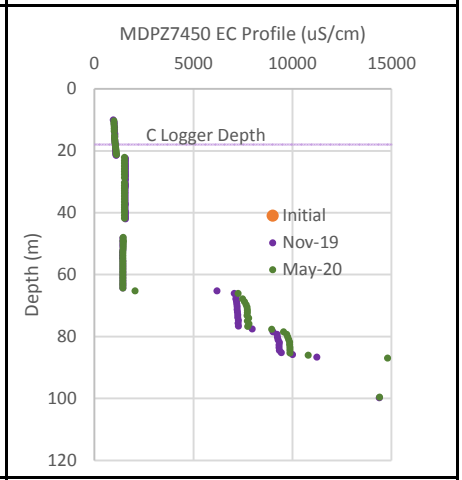
	Sample Date:	Nov-19	May-20	Mar/Aug-21	Dec-21	Jul-22	Oct-22	May-23	Nov-23
Bore	Year of Installation	Water Type	Water Type	Water Type	Water Type	Water Type	Water Type	Water Type	Water Type
MDPZ7449A	2018	5	5	5	5	5	5	5	5
MDPZ7449B	2018	9	8	9	6	5	6	5	8
MDPZ7449C	2018	9	8	8	8	6	8	8	8
MDPZ7450A	2018	9	9	9	9	9	9	9	9
MDPZ7450B	2018	5	5	6	5	5	5	5	5
MDPZ7450C	2018	6	3	6	3	9	6	8	8
MDPZ7451A	2018	9	9	9	9	9	9	9	9
MDPZ7451B	2018	9	9	9	9	9	9	9	9
MDPZ7451C	2018	9	9	9	9	9	9	9	9
MDPZ7452A	2018	9	9	9	9	9	9	9	9
MDPZ7452B	2018	9	9	9	9	9	9	9	9
MDPZ7452C	2018	9	9	9	9	9	9	9	9
MDPZ7453A	2018	9	9	9	9	9	9	9	9
MDPZ7453B	2018	9	9	9	9	9	9	9	9
MDPZ7453C	2018	9	9	9	9	9	9	9	9
MDPZ7454	2019	5	6	6	5	6	6	6	6
MDPZ7455	2019	5	5	5	5	5	5	5	N/A
MDPZ7456A	2019	9	9	9	9	9	9	9	9
MDPZ7456B	2019	9	9	9	9	9	9	9	9
MDPZ7456C	2019	9	9	9	9	9	9	9	9
MDPZ7457A	2019	9	9	9	9	9	9	9	9
MDPZ7457B	2019	9	9	9	9	9	9	9	9
MDPZ7457C	2019	9	9	9	9	9	9	9	9
MDPZ7458A	2019	9	9	9	9	9	9	9	9
MDPZ7458B	2019	9	9	9	9	9	9	9	9
MDPZ7458C	2019	9	9	9	9	9	9	9	9
MDPZ7459	2019	1	2	2	2	2	2	2	2
MDPZ7460A	2019	9	9	9	9	9	9	9	9
MDPZ7460B	2019	9	9	9	9	9	9	9	9
MDPZ7460C	2019	9	9	9	9	9	9	9	9
MDPZ7461	2019	9	9	9	9	9	9	9	9
MDPZ7462A	2019	9	9	N/A	N/A	N/A	N/A	N/A	N/A
MDPZ7462B	2019	9	9	N/A	N/A	N/A	N/A	N/A	N/A
MDPZ7462C	2019	9	9	N/A	N/A	N/A	N/A	N/A	N/A
MDPZ7463 Lower	2019	9	9	9	9	9	9	9	9
MDPZ7463 Upper	2019	9	9	9	9	9	9	9	9
MDPZ7464 Lower	2019	9	9	9	9	9	9	9	9
MDPZ7464 Upper	2019	6	6	8	6	6	6	6	3
MDPZ7465	2019	9	9	N/A	N/A	9	9	9	9
MDPZ7466 Lower	2019	5	5	5	6	5	6	5	5
MDPZ7466 Upper	2019	9	9	6	9	9	8	9	9
MDPZ7467 Lower	2019	5	5	5	5	5	5	5	5
MDPZ7467 Upper	2019	5	5	5	5	5	5	5	5
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MDPZ7468B	2019	9	9	9	9	9	9	9	9
MDPZ7468C	2019	9	9	9	9	9	9	9	9
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MDPZ7469B	2019	9	9	9	9	9	9	9	9
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MDPZ7471B	2019	9	9	9	9	9	9	9	9
MDPZ7471C	2019	9	9	9	9	9	9	9	9
MDPZ9205	2021	N/A	N/A	N/A	N/A	9	9	9	9
MDPZ9211	2021	N/A	N/A	N/A	9	9	9	9	9
MDPZ9212D	2021	N/A	N/A	N/A	9	9	9	9	9
MDPZ9212S	2021	N/A	N/A	N/A	9	9	9	9	9
MDPZ9213	2021	N/A	N/A	N/A	N/A	5	5	5	5
MDPZ9214	2021	N/A	N/A	N/A	9	9	9	9	9
MDPZ9215D	2021	N/A	N/A	N/A	9	9	9	9	9
MDPZ9215S	2021	N/A	N/A	N/A	9	9	9	9	9
MDPZ9216	2021	N/A	N/A	N/A	9	9	9	9	9
MDPZ9217	2021	N/A	N/A	N/A	9	9	9	9	9
MDPZ9218	2021	N/A	N/A	N/A	9	9	9	9	9
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MDPZ9221	2021	N/A	N/A	N/A	9	9	9	9	9
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MDPZ9224S	2023	N/A	N/A	N/A	N/A	N/A	N/A	N/A	9
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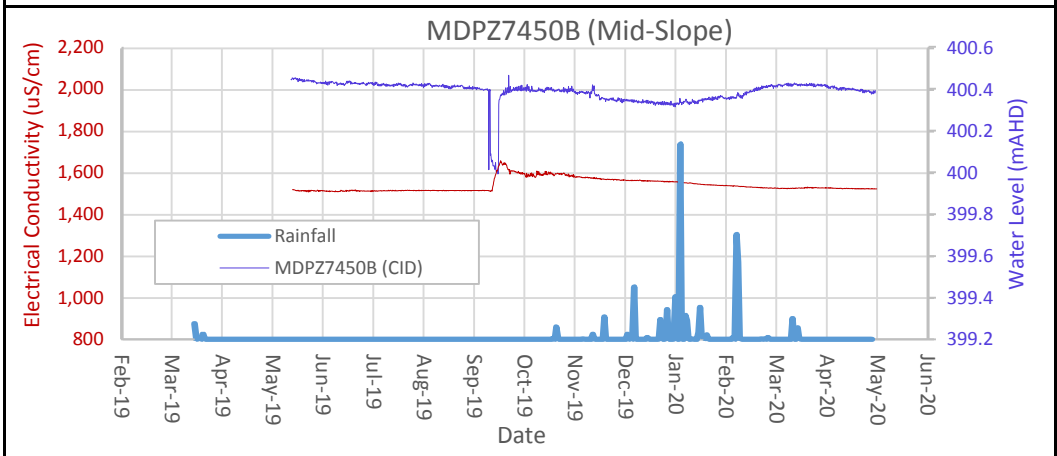
APPENDIX K
SELECTED BASELINE EC HYDROGRAPHS

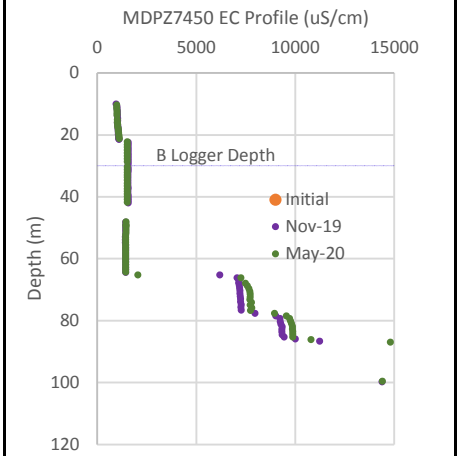


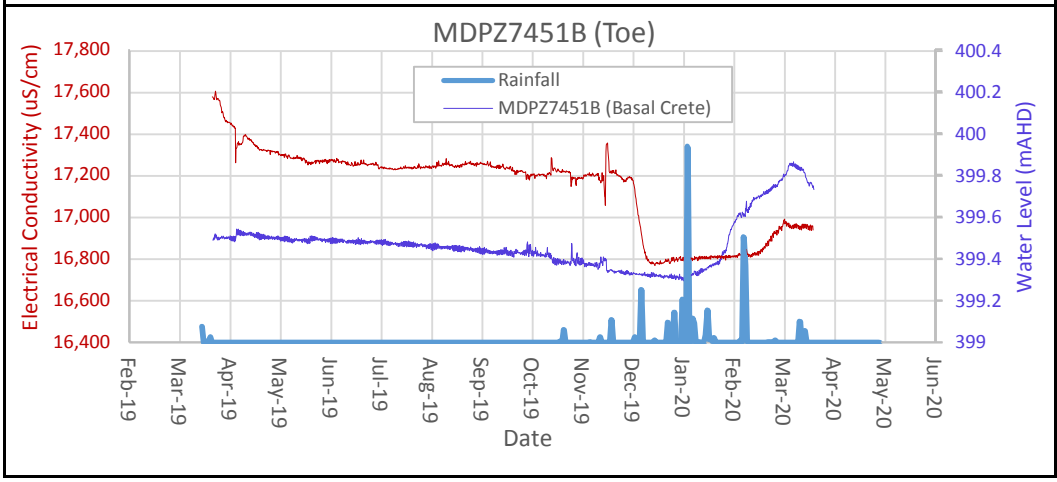


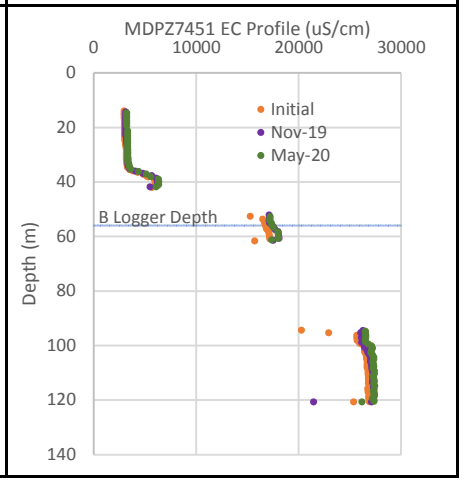






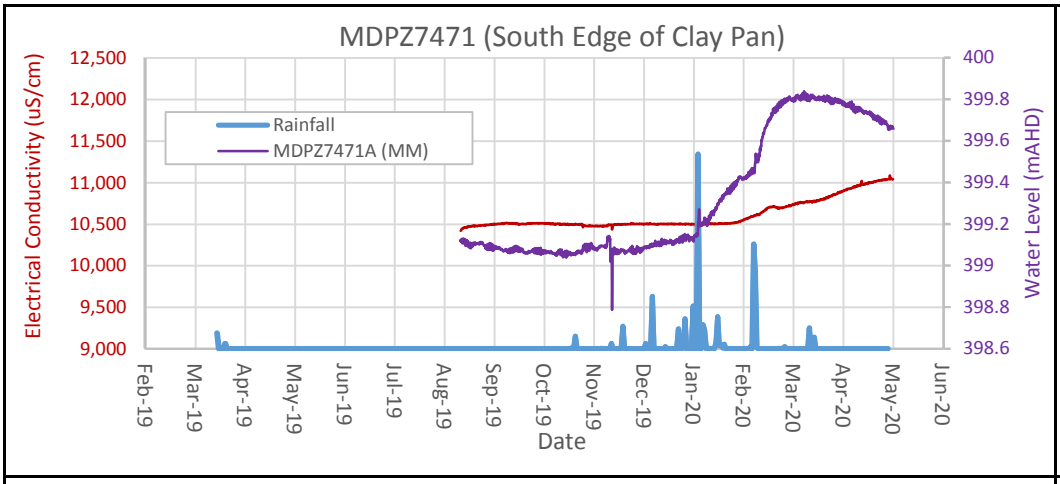


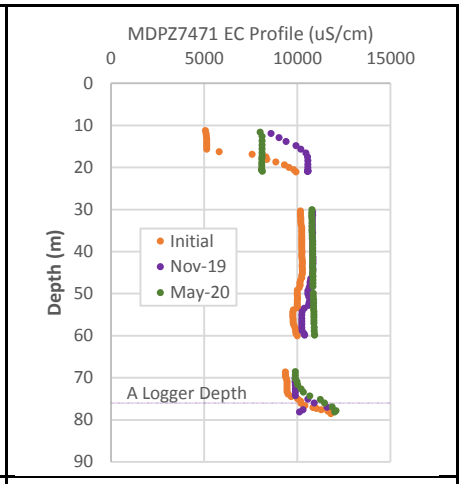


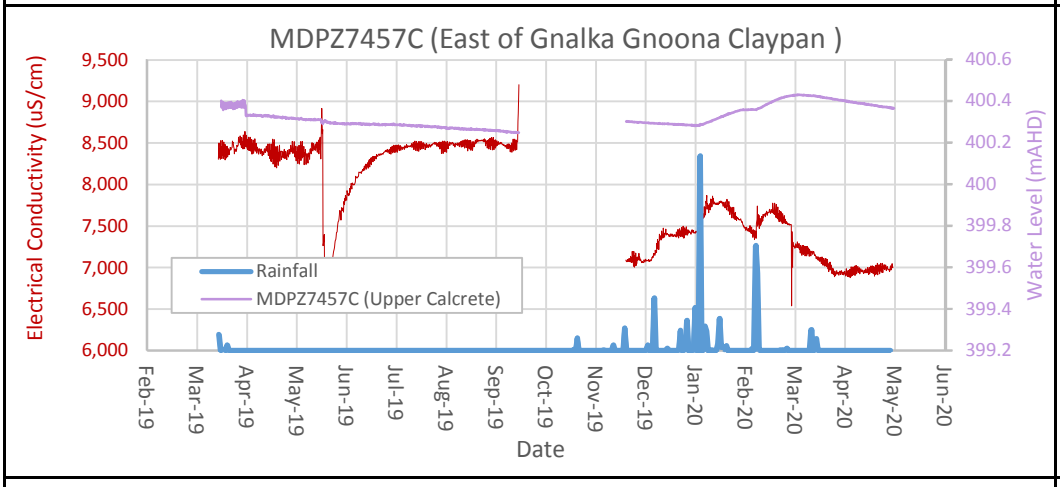


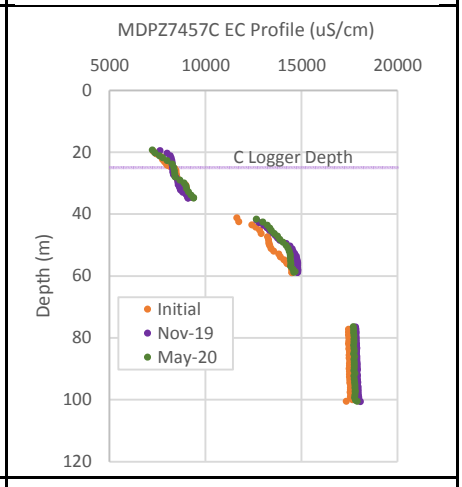
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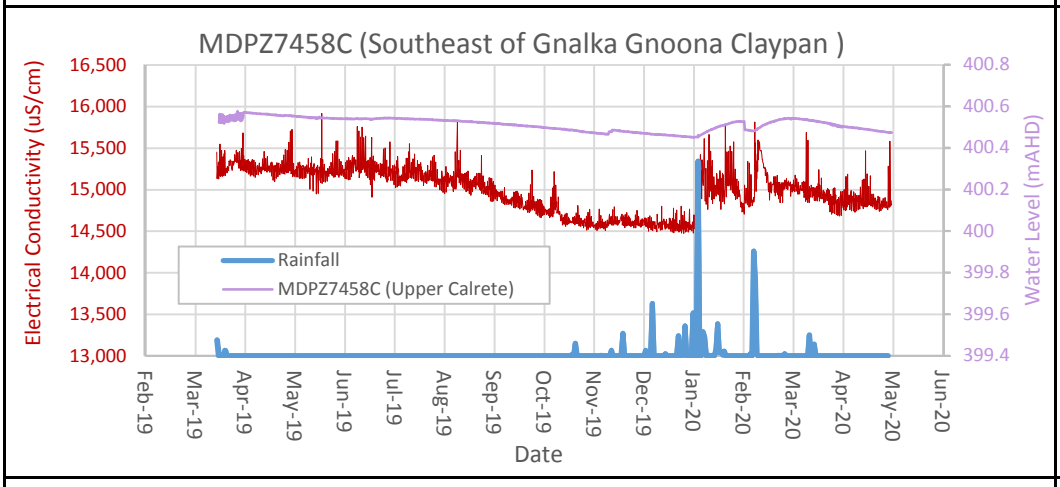
Salinity Hydrographs Northern Alluvial Fan

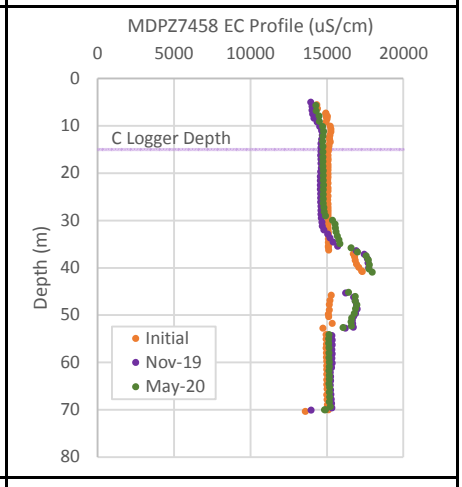


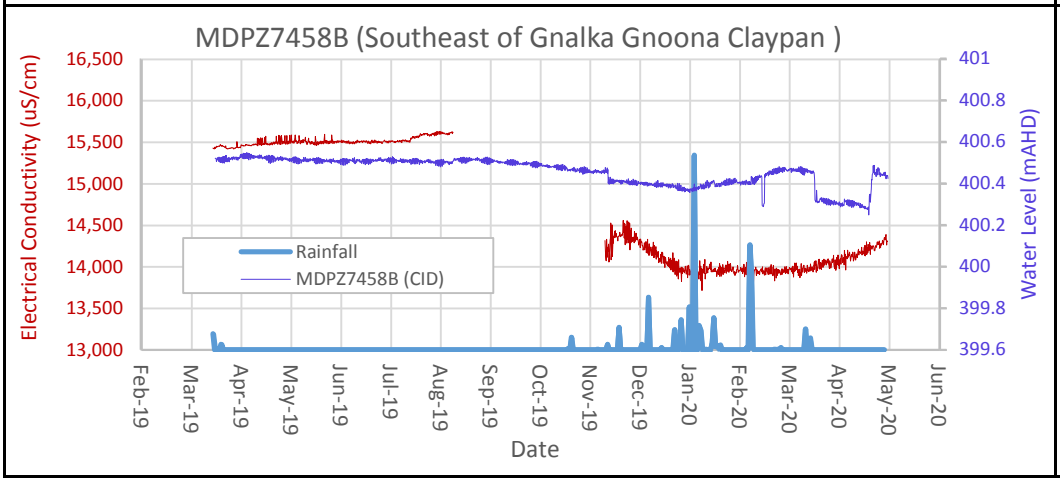


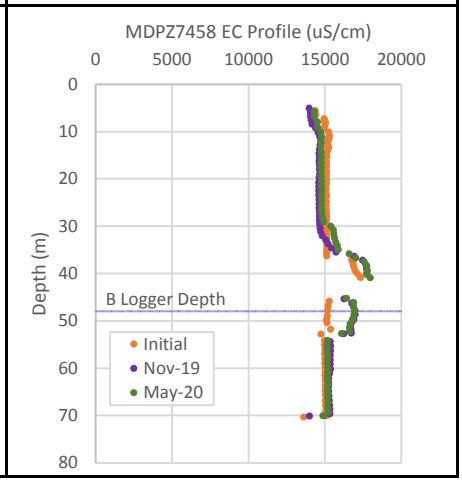




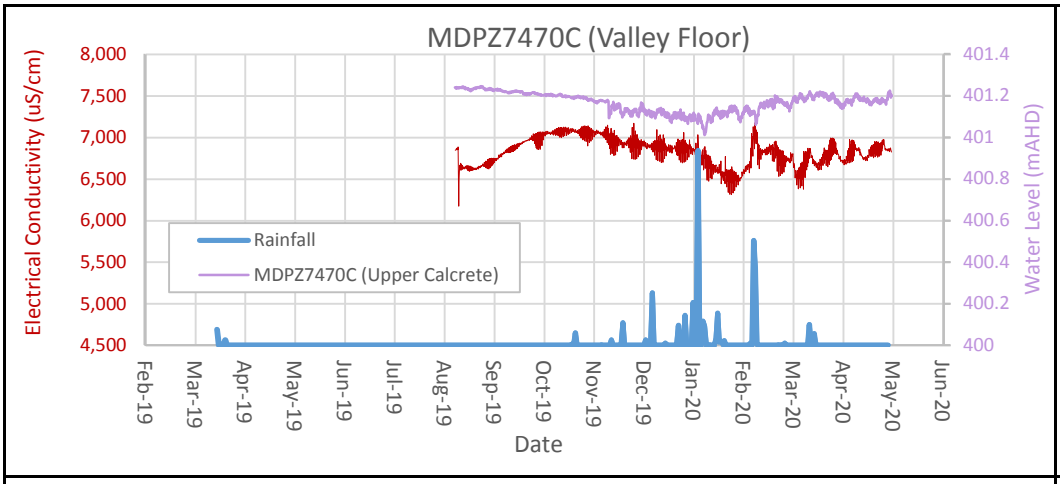


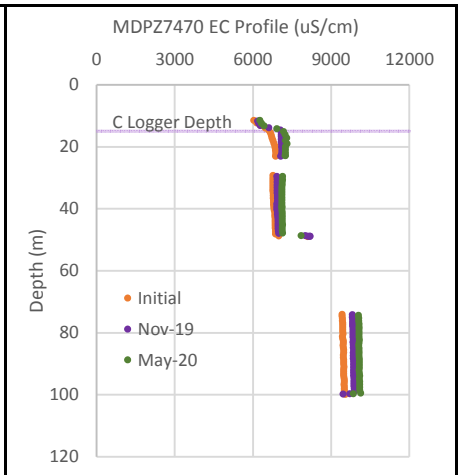


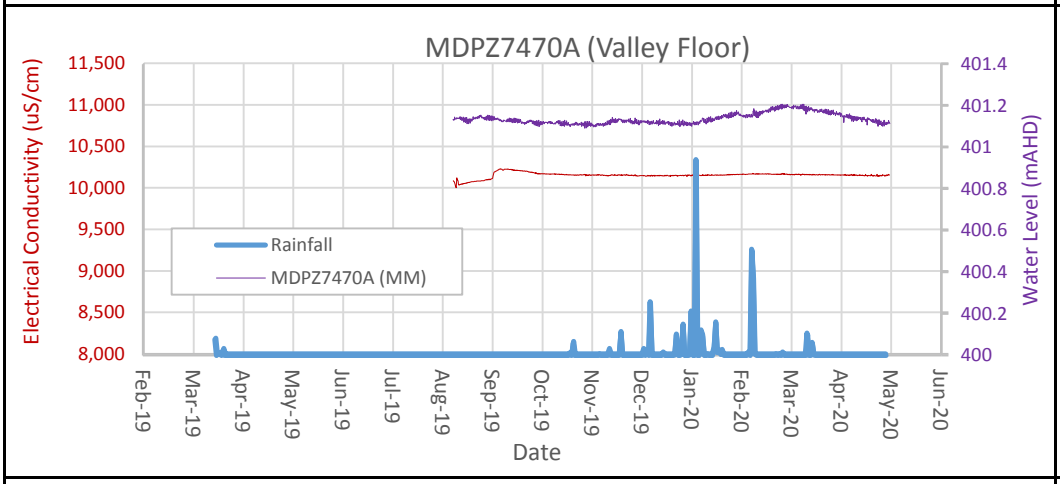


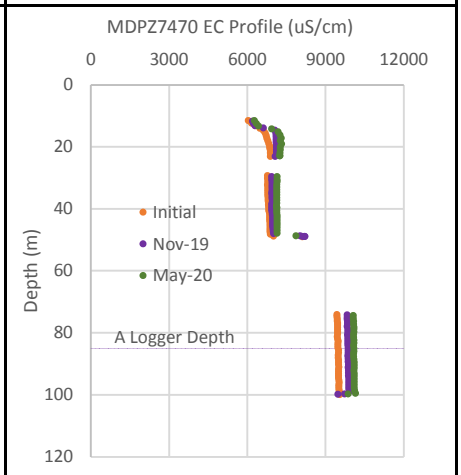


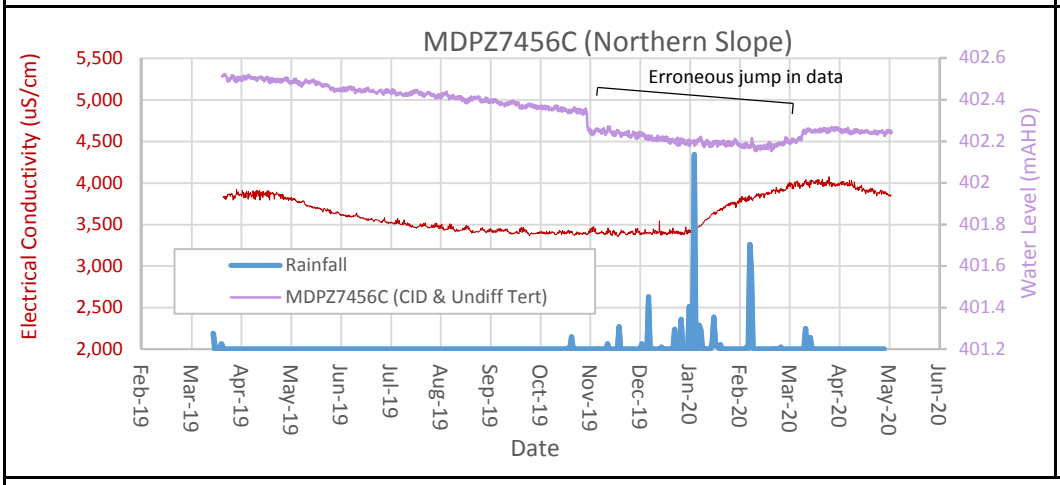
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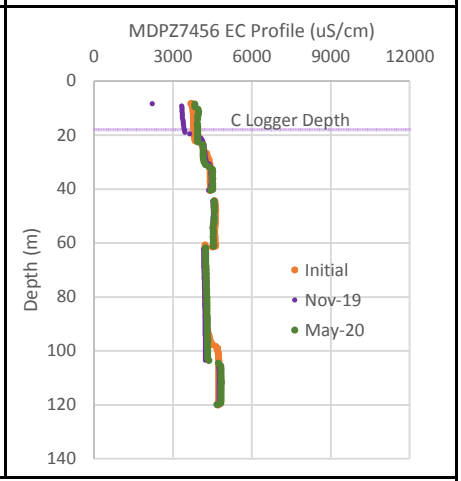




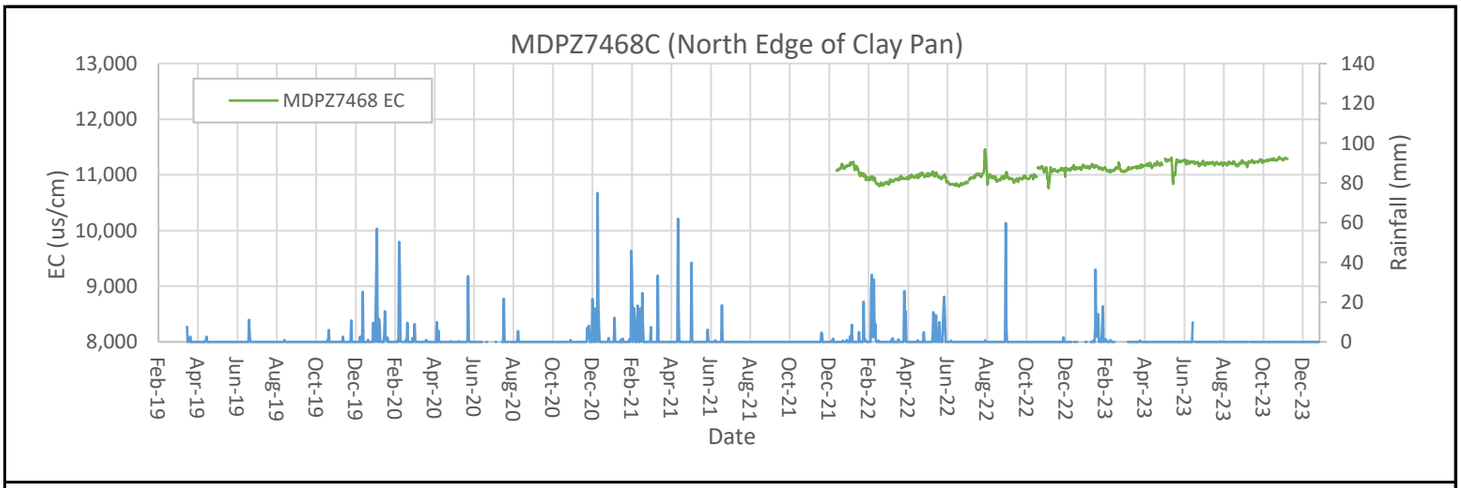


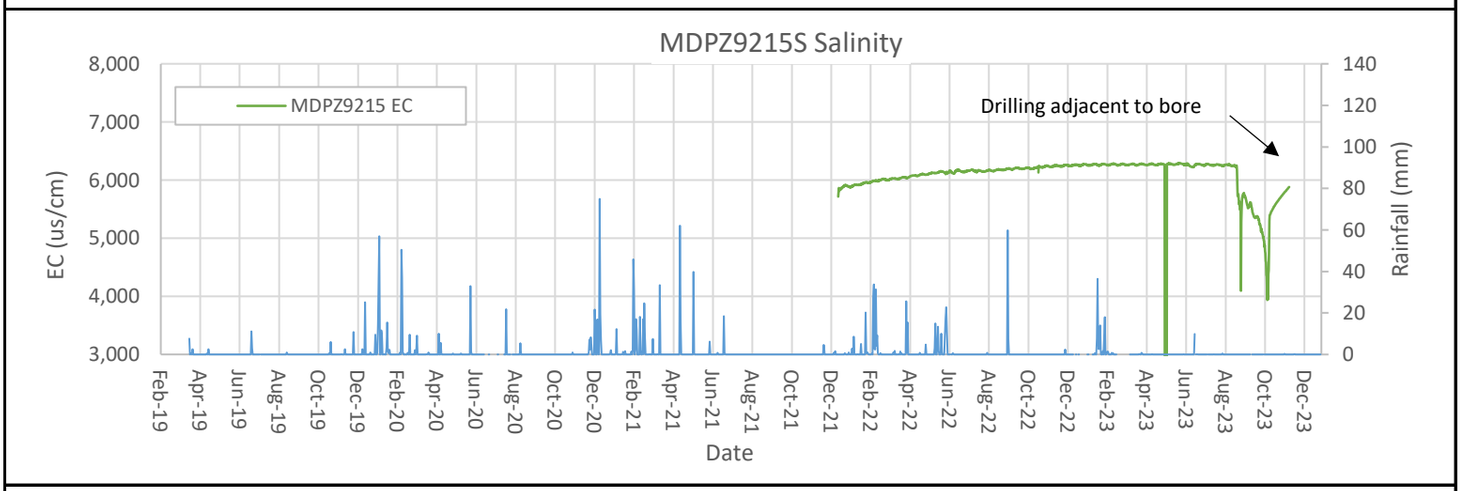


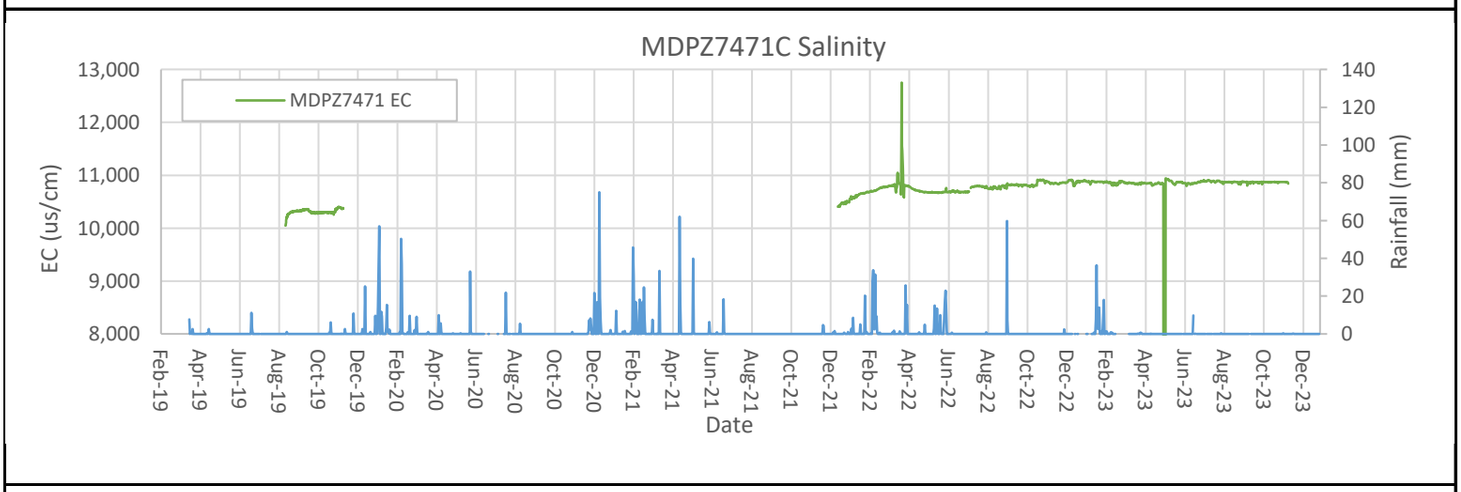


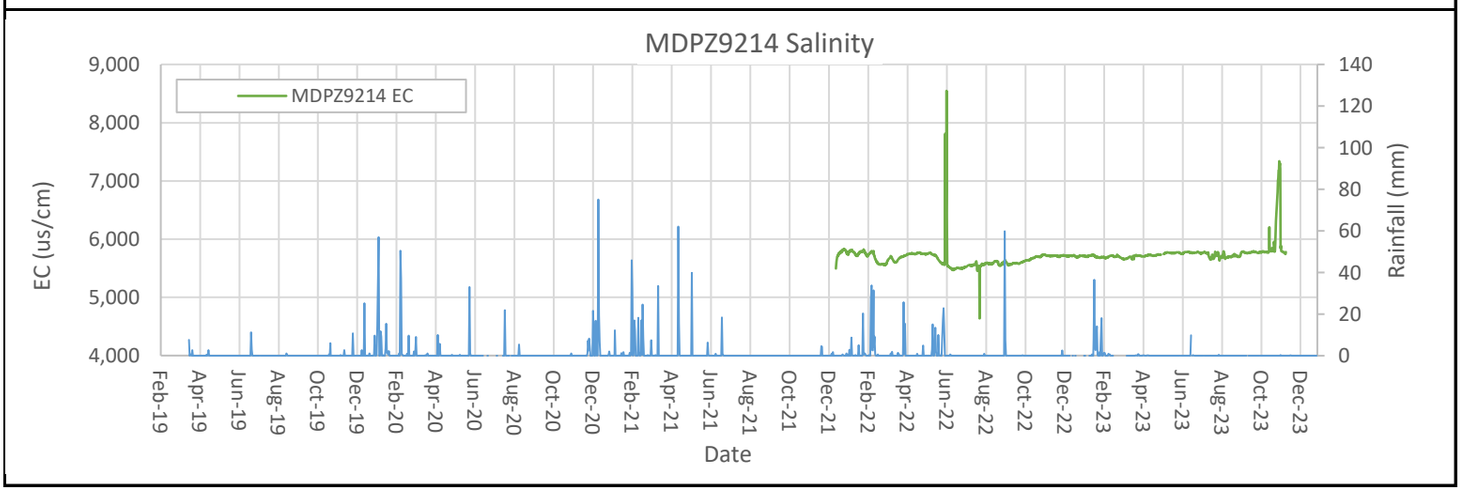


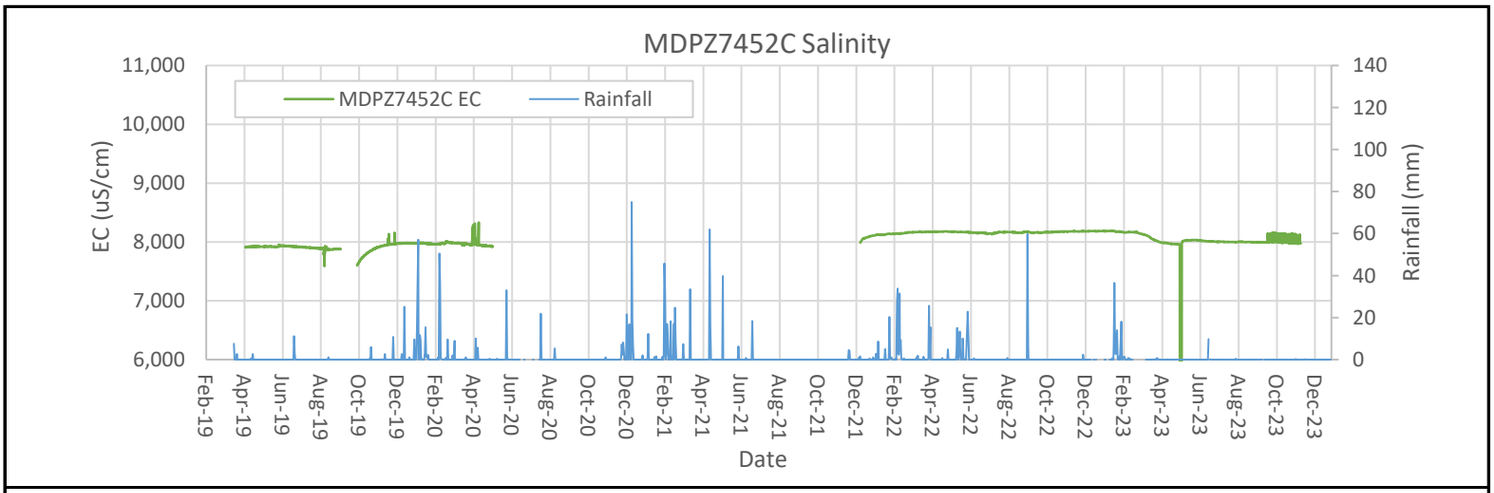
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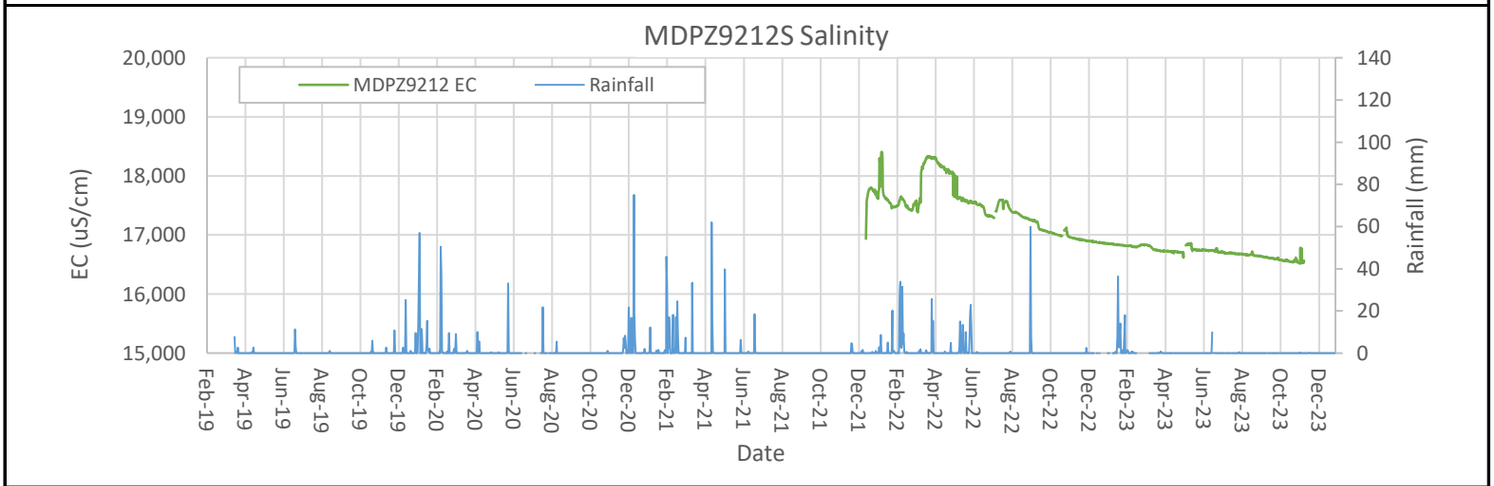

MDPZ7468C (North Edge of Clay Pan)
MDPZ7468 EC
EC (us/cm)
Rainfall (mm)
Date

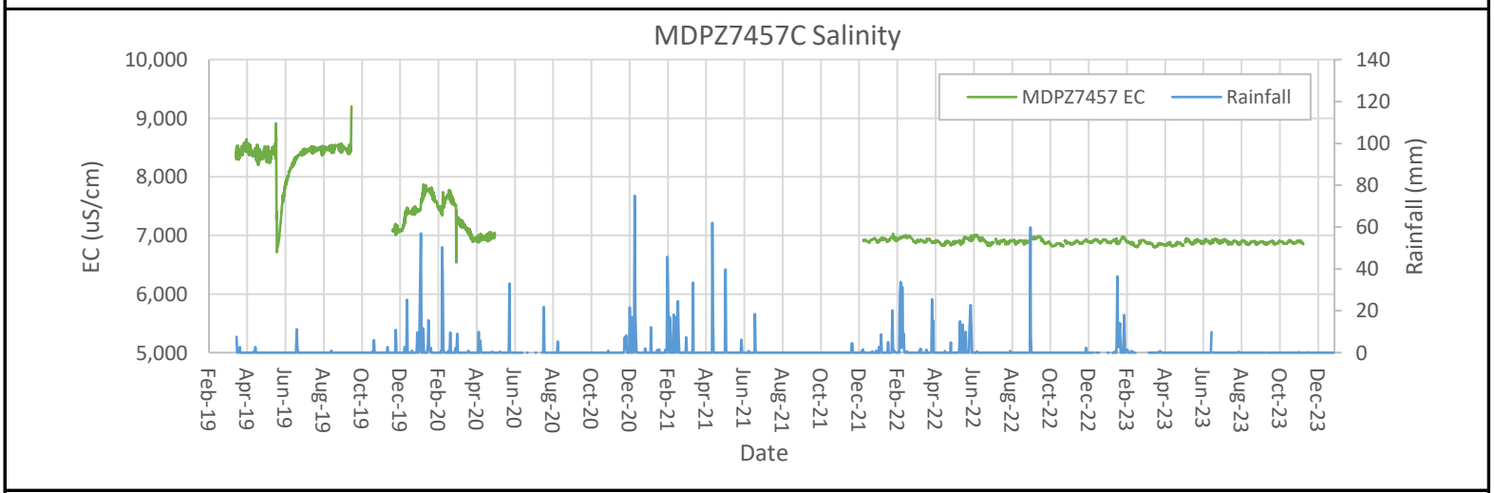

MDPZ9215S Salinity
MDPZ9215 EC
Drilling adjacent to bore
EC (us/cm)
Rainfall (mm)
Date

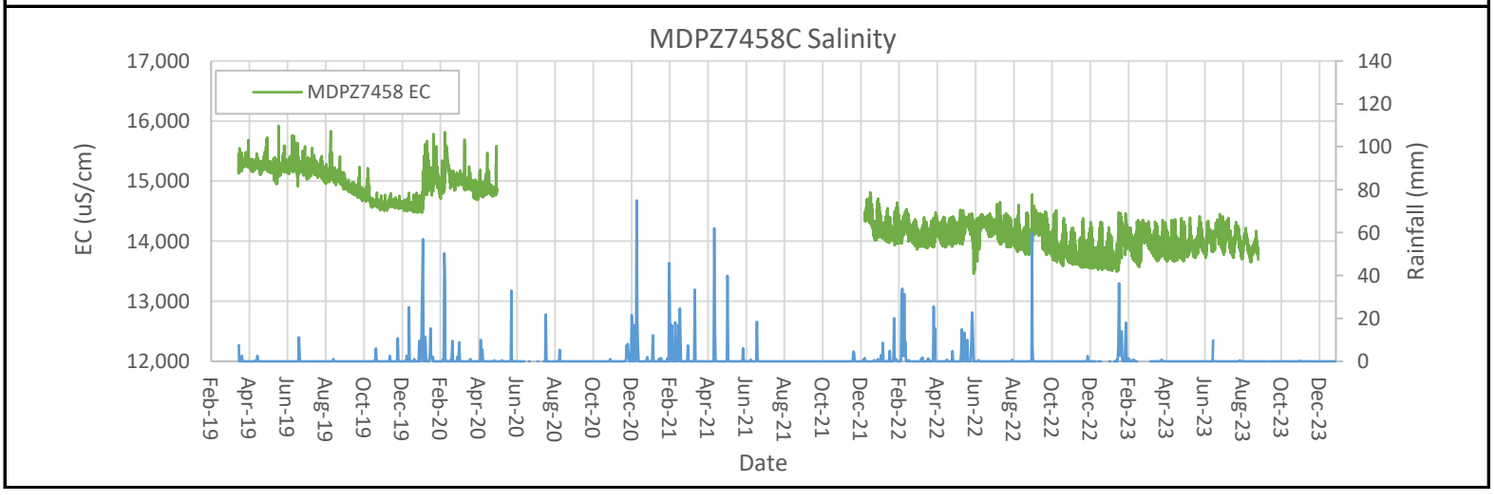

MDPZ7471C Salinity
MDPZ7471 EC
EC (us/cm)
Rainfall (mm)
Date

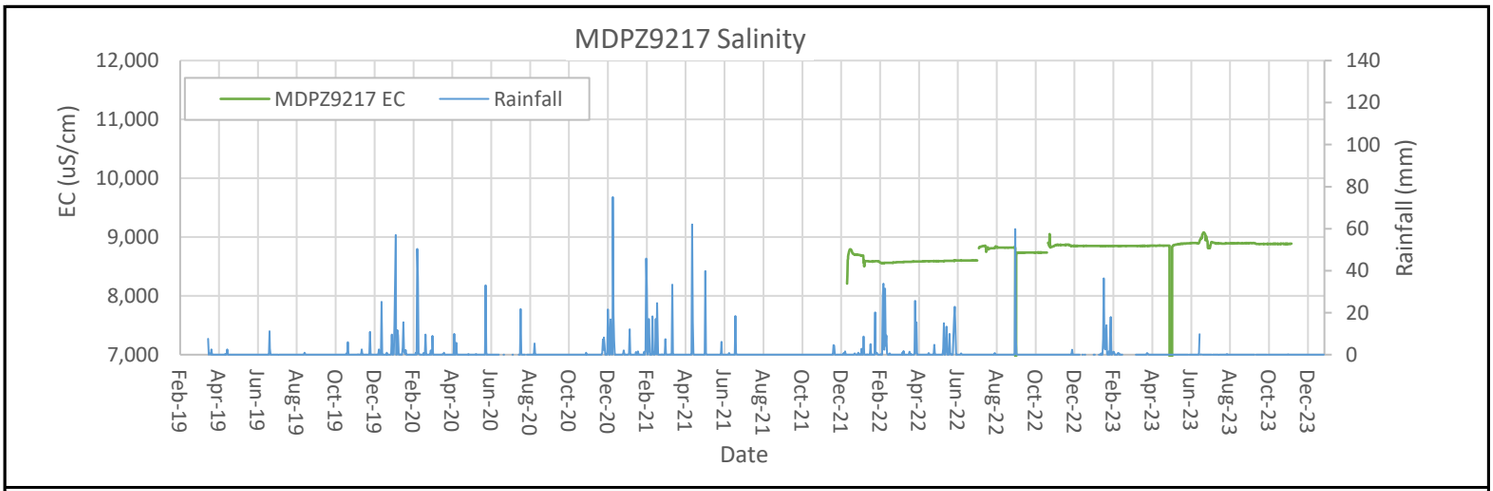

MDPZ9214 Salinity
MDPZ9214 EC
EC (us/cm)
Rainfall (mm)
Date

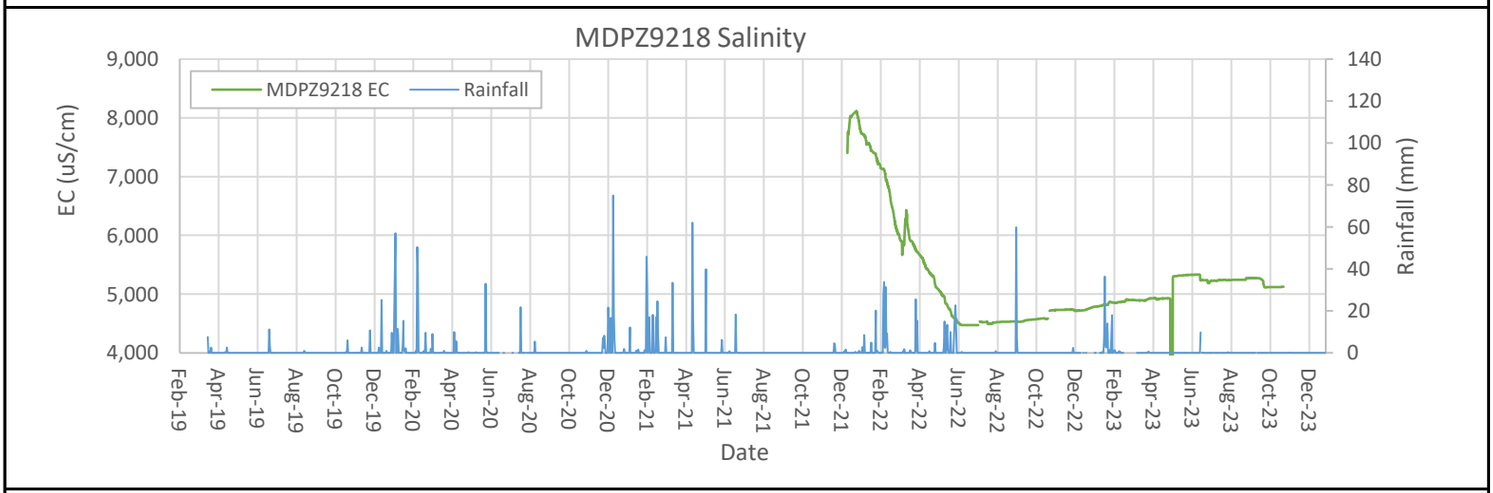

MDPZ7452C Salinity
MDPZ7452C EC
Rainfall
EC (uS/cm)
Rainfall (mm)
Date

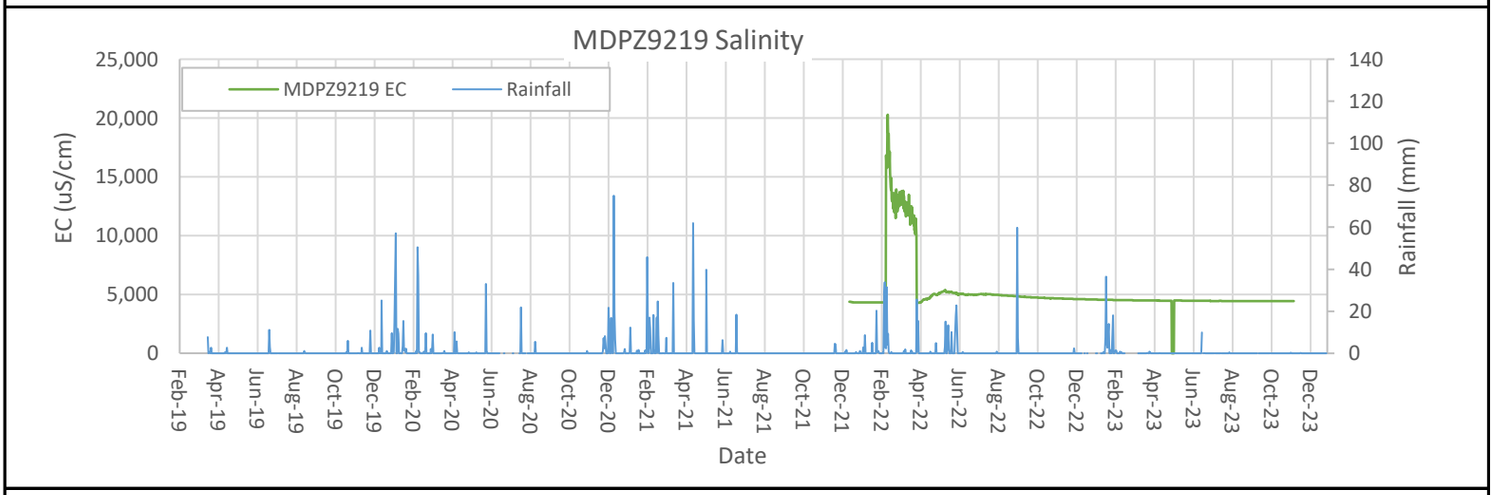

MDPZ9212S Salinity
MDPZ9212 EC
Rainfall
EC (uS/cm)
Rainfall (mm)
Date

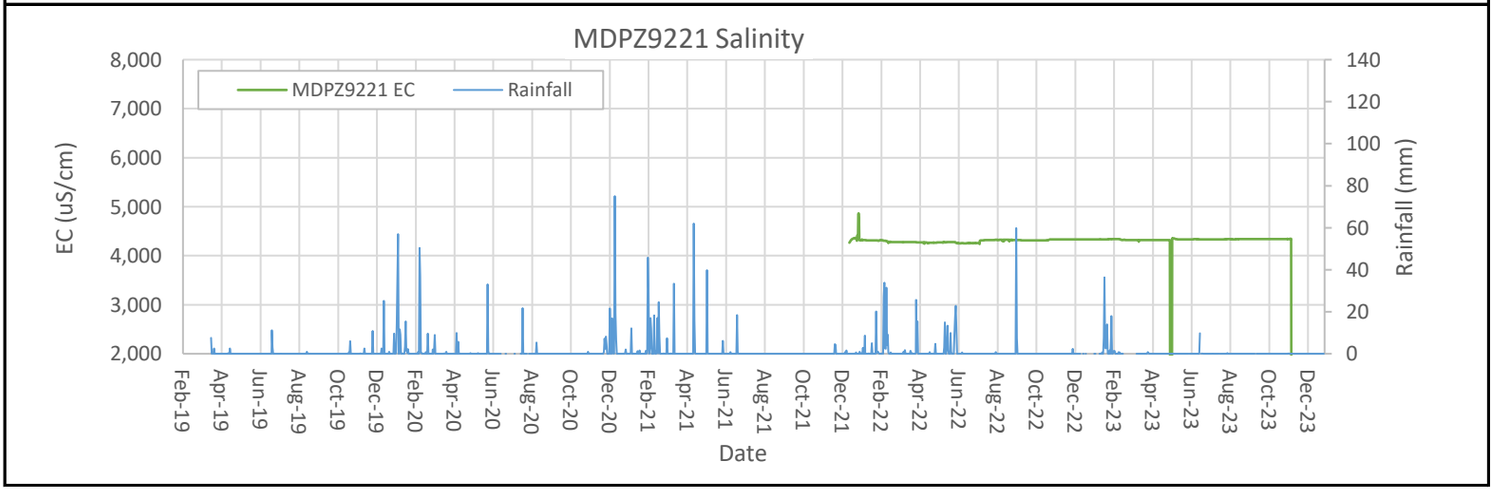

MDPZ7457C Salinity
MDPZ7457 EC
Rainfall
EC (uS/cm)
Rainfall (mm)
Date


MDPZ7458C Salinity
MDPZ7458 EC
EC (uS/cm)
Rainfall (mm)
Date


MDPZ9217 Salinity
MDPZ9217 EC
Rainfall
EC (uS/cm)
Rainfall (mm)
Date


MDPZ9218 Salinity
MDPZ9218 EC
Rainfall
EC (uS/cm)
Rainfall (mm)
Date


MDPZ9219 Salinity
MDPZ9219 EC
Rainfall
EC (uS/cm)
Rainfall (mm)
Date


MDPZ9221 Salinity
MDPZ9221 EC
Rainfall
EC (uS/cm)
Rainfall (mm)
Date

APPENDIX L
ECOHYDROLOGICAL BACKGROUND CONCEPTS

1. ECOHYDROLOGICAL BACKGROUND CONCEPTS

1.1 Vegetation Water Sources

Plant available water varies both spatially and temporally in the soil/regolith accessible to plant roots. Plants have evolved a range of strategies for extracting this water. At any given location, it is common for different plant species to target different water sources; an attribute of vegetation communities referred to as hydrological niche segregation (Silvertown et al. 2015; Illuminati et al 2022). An understanding of plant water use strategies is important for predicting vegetation responses to changes in surface or groundwater regimes.

For the purposes of this discussion, four broad, plant functional water use types are recognised (Figure 1.1):

a) Transient opportunistic – drought avoiding species with shallow root systems; key traits include ephemeral life history and rapid response to rainfall pulses.

b) Conservative shallow rooted – drought tolerating species with shallow root systems; typically exhibit a variety of adaptations enabling persistence during dry phases (e.g. strong stomatal sensitivity/regulation, dormancy and/or succulence). Relevant examples from the Pilbara include Spinifex (*Triodia* spp). and Mulga (*Acacia aneura* species complex).

c) Deep rooted – drought avoiding species with deep root systems, enabling access to stored water in deep subsoil layers. Necessarily restricted to deep soil profiles, typically with interannual storage capacity. The most mesic of species within this group occur in areas where lateral inflows are large relative to direct rainfall (e.g. drainage lines and floodplains). Relevant examples from the Pilbara include *Acacia pruinocarpa* and *A. citrinoviridis*.

d) Phreatophytic – species that use groundwater in persistent or permanent aquifers to meet some or all of their water use requirements (i.e. a drought avoidance strategy). Access to groundwater may be variable as dictated by site hydrology. Obligate phreatophytic species are dependent on groundwater. In landscapes such as the Pilbara groundwater is generally deep and inaccessible to vegetation, hence obligate phreatophytic have restricted distributions (e.g. *Melaleuca argentea*). Facultative phreatophytes can opportunistically use groundwater to augment vadose zone sources, thereby enabling them to compete and persist in a broader range of habitats; relevant examples in the Pilbara include *Eucalyptus camaldulensis* and *E. victrix*.

The composition of functional water use types within a vegetation community varies with landscape setting. Many vegetation communities in dryland environments are consistent with the 'two-layer hypothesis', which predicts that different plant species are able to coexist because they utilise water from different depths (Matos et al. 2022). Deeper rooted plants can respond to heterogeneously distributed soil moisture in various ways including (Thomas et al. 2020):

- Compensated root water uptake - in which water requirements of the plant under limiting soil moisture conditions are fulfilled by enhanced uptake from the wettest root zone,
- Hydraulic redistribution - the passive transfer of soil moisture via the root system from a region of high water potential (i.e. wet soil) to low water potential (i.e. dry soil), and
- Adaptive root growth in response to soil water and nutrients.

In practice, most plants have a degree of adaptability to the growing conditions that they experience. Consequently, they may occupy a spectrum of functional behaviours across their range of occurrence and also over their life cycles (e.g. seedlings versus mature trees). Even within a given population, the importance of different water sources may vary amongst individuals of the same species.

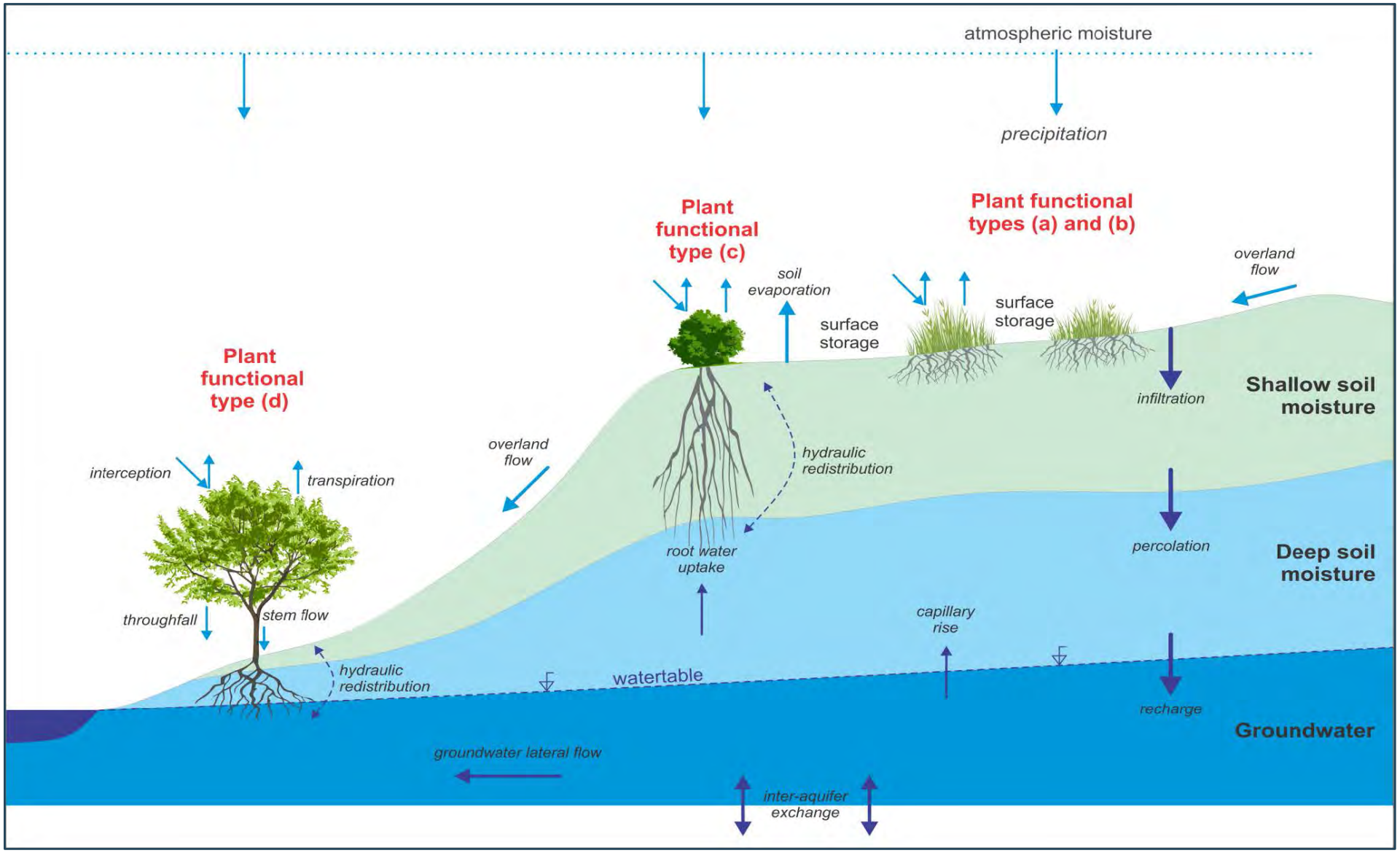


Figure 1.1 A conceptual diagram depicting plant functional types based on water use strategies (adapted from Miller et al. 2012; as presented in MWH 2015)

Groundwater use by vegetation is relatively uncommon and most plants preferentially use water from shallow layers when it is available (Amin et al. 2020). As a consequence of this, the relative importance of groundwater decreases with increasing annual rainfall and vadose zone thickness/water storage capacity (Glanville et al. 2023). Global experience suggests that groundwater uptake is more related to site-specific environmental conditions rather than the capabilities of a given plant species (Thomas, 2014).

Recent scientific investigations have also confirmed that many plants can supplement soil water sources via direct uptake through stems or leaves; involving the exploitation of dew, fog or small precipitation events that wet the canopy but not the soil (Gimeno et al. 2022; Matos et al. 2022). The significance of this uptake mechanism in Pilbara vegetation species is unknown but cannot be discounted.

1.2 Tree Water Uptake

Plant water use involves soil water uptake and transfer to the atmosphere via hydraulic pathways within roots, stems and leaves (Novick et al. 2022). The process is driven by water potential (Ψ) gradients through the soil–plant–atmosphere continuum.

In the case of trees and other woody plants, water use can be estimated based on the theory of functional convergence between water use and leaf area; which posits that trees of similar size transpire similar amounts of water under equivalent growing conditions (Zeppel, 2013). This theory is based on fundamental ecophysiological solutions used by trees to optimise the balance between water use and carbon fixation, which is strongly supported across a broad range of tree species globally (Forrester et al. 2022; Sohel, 2022; Tfwala et al. 2019).

Several independent studies of tree water use by riparian Eucalypts in the Pilbara have found similar relationships between tree size and tree water use including:

- Pfautsch et al. (2011) - reported annual water use of 405 mm/year in a dense woodland of *E. victrix* (tree densities of 180 to 200 trees/ha) growing with unrestricted access to shallow groundwater near Millstream. The largest tree at this site (DBH = 58 cm) transpired up to 8,000 L/month (equivalent to about 270 L/day); whilst average sized trees (DBH 20 to 40 cm) transpired in the order of 30 - 100 L/tree/day.
- Pfautsch et al. (2014) - reported daily transpiration in the order of 10 to 240 L/tree/day for *E. victrix* trees spanning a DBH range of approximately 20 to 75 cm growing along the lower Weeli Wolli Creek system. The water use of trees with perennial access to abundant moisture was more than double that of trees growing in drier settings, indicating the effect of site conditions on water use regulation behaviour.
- RTIO (2011) – reported water use of up to 135 L/tree/day in for *E. victrix* trees growing in woodlands at the Mount Bruce Flats. Average tree water use was strongly related to tree size/sapwood area.
- Sap flow measurements undertaken by Astron Environmental Services as evaluated and discussed in AQ2 (2015) reported water use rates for *E. victrix* trees growing in woodlands at Coondewanna Flats in the range of 20 to 200 L/tree/day. Average tree water use was strongly related to tree size/sapwood area.

These results are also consistent with multiple tree water use studies from other parts of Australia (e.g. as reviewed by Zeppel 2013).

Trees must regulate their water transfer processes to prevent excessive water loss and maintain the integrity of the hydraulic transfer network (Cai et al. 2023). This is primarily achieved via stomatal regulation at the leaf – atmosphere interface, which is triggered by one or a combination of drying soil and excessive atmospheric demand. Therefore, for a given tree, daily water use is responsive to environmental

conditions. All else being equal, trees with abundant water will transpire more than trees with constrained water supply.

Over time periods spanning multiple seasonal cycles, average daily tree water use will tend to converge to values that reflect 'site quality' with respect to plant water availability. In this context, site quality is defined as the capacity of a site to sustain tree water use over long periods. For riparian trees in the Pilbara, quantitative tree water use measurements at Coondewanna Flats (AQ2 2015) and Millstream (Pfautsch et al. 2011) provide plausible lower and upper bounds of long term, mean daily tree water use as influenced by 'site quality' (Figure 1.2, top). The ability of trees to access groundwater is an important factor affecting site quality; at the time of these studies the water table was approximately 20 mbgl at Coondewanna Flats (groundwater inferred to not be used by trees) and 2 mbgl at Millstream (groundwater inferred to be the primary water source used by trees).

1.3 Vegetation Structure, Plant Traits and Water Availability

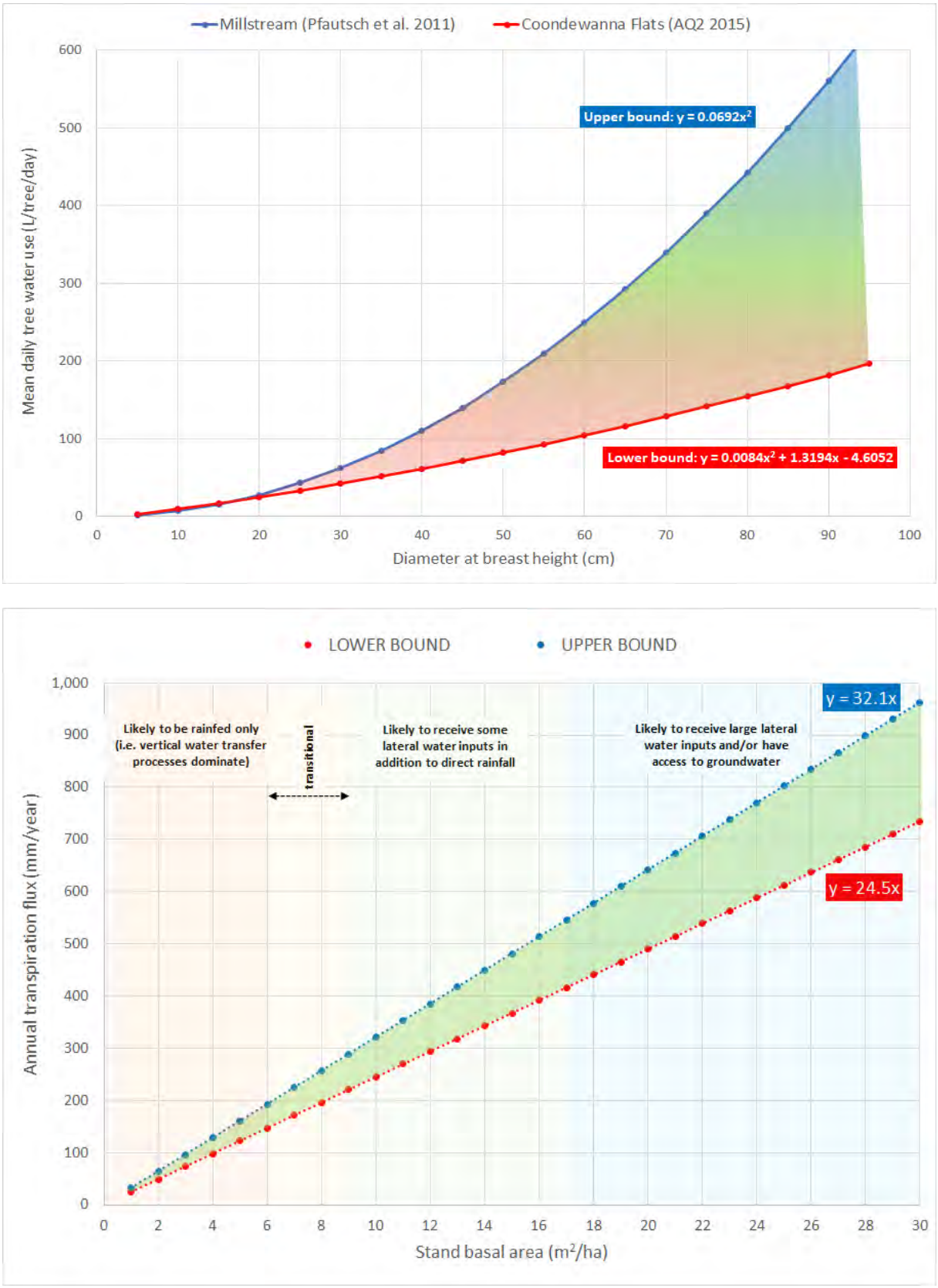
As part of understanding the landscape water balance, it is common for individual tree water use estimates to be 'upscaled' to the stand level. By extension, structural characteristics of vegetation can provide insights into landscape water availability and water sources used by vegetation in accordance with the principle of ecological optimality (O'Grady et al. 2011; Ellis and Hatton 2008). This principle suggests that over extended time scales, vegetation in water limited environments will equilibrate with climate and soils to optimally use the available soil water. Important structural vegetation metrics that scale with water availability include tree height, leaf area index (LAI[1]) and stand basal area[2] (SBA). The upscaled tree level relationship for Pilbara riparian trees is shown in Figure 1.2 (bottom). Taking into account assumptions relating to vadose zone thickness and the plant available water (PAW) storage capacity of the soil, typically Pilbara woodlands with a basal area of less than about 6 to 9 m^2/ha are likely to derive all of their water requirements from direct rainfall inputs[3]. Another example of an SBA relationship across a gradient of rainfall and potential evapotranspiration is that of savannah vegetation in northern Australia compiled by Murphy et al. (2023) (Figure 1.3).

Careful consideration of site attributes, tree species, population structures and dynamics is necessary when making inferences about ecological optimality. Different species may have quite different water use regulation behaviours under similar soil moisture and climate regimes. Disturbance factors affecting tree recruitment and mortality (e.g. fire frequency) can reduce tree populations below the 'hydrological carrying capacity' of a given site at least for periods of time.

Various ecophysiological plant traits also correlate with site water availability, leaf turgor loss point, leaf and sapwood hydraulic conductivity, Huber Value (the ratio of leaf area to sapwood area), sensitivity to xylem embolism and above ground net primary productivity (Eamus et al. 2015). Tree growth, typically measured as a time series of diameter at breast height (DBH[4]) or basal area increments, correlates with water availability and is therefore a useful measurement for understanding site quality.

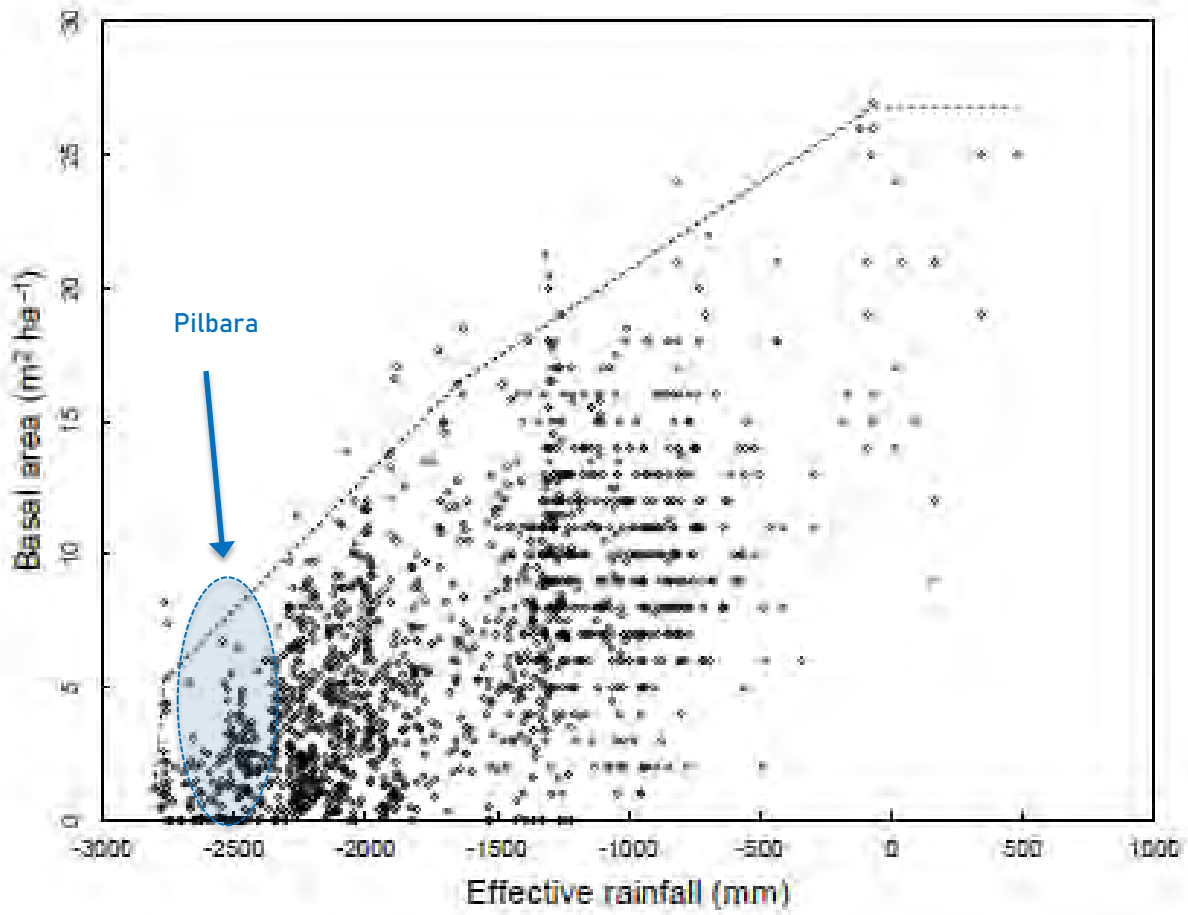
Changed hydrological regimes tend to result in altered vegetation structure: for example increased recruitment and growth in the case of increased water availability, or selective tree deaths ('self thinning') and less recruitment in the case of reduced water availability. A summary of typical vegetation responses to increased depth to groundwater is shown in Figure 1.4.

[1] LAI is the single sided leaf area within a given (vertically projected) area of land).
[2] The cross sectional area of all plant stems within a given area of land.
[3] Note that this may not apply in some landscape/soil type contexts.
[4] 130 cm above ground level.



Top: Tree level relationships Bottom: Stand level relationships

Figure 1.2 Tree water use relationships used to estimate long term, mean daily transpiration flux



The dashed line represents the predictions of a non-parametric piecewise quantile regression (99th percentile), approximating the 'upper bound' of basal area. Comparison with Pilbara effective rainfall indicated by blue arrow.

Figure 1.3 The relationship between tree basal area and effective rainfall (mean annual rainfall – mean annual point potential evapotranspiration) in Australian savannas (reproduced from Murphy et al. 2023)

Table 4. The meaning of the abbreviations/traits used in Fig. 7.

Abbreviation	Explanation/definition
Ψ_{TLP}	The water potential of leaves at which turgor is zero
$\prod_{100}$	The solute potential at a relative water content of 100 %
RWC_{TLP}	The relative water content at which leaf turgor is zero
SWD	The saturated water content of wood
K_S	Sapwood-specific hydraulic conductivity of branch xylem
K_L	Leaf-specific hydraulic conductivity of branch xylem
PLC_{50}	The water potential at which 50 % of the hydraulic conductivity is lost
PLC_{88}	The water potential at which 88 % of the hydraulic conductivity is lost
H_V	Huber value: the ratio of leaf area to sapwood area
BA	Total basal area of trees within a plot
LAI	Leaf area index of a stand of trees
AGB	Above-ground biomass
ANPP	Above-ground net primary productivity
WUE	Water-use efficiency; calculated as the ratio of ANPP/stand water use
Height	Average height of the trees in a plot
Water use	Rates of stand water use; up-scaled from sap flow measurements
Stem density	The number of trees per hectare
Litterfall	Rates of annual litterfall within a plot

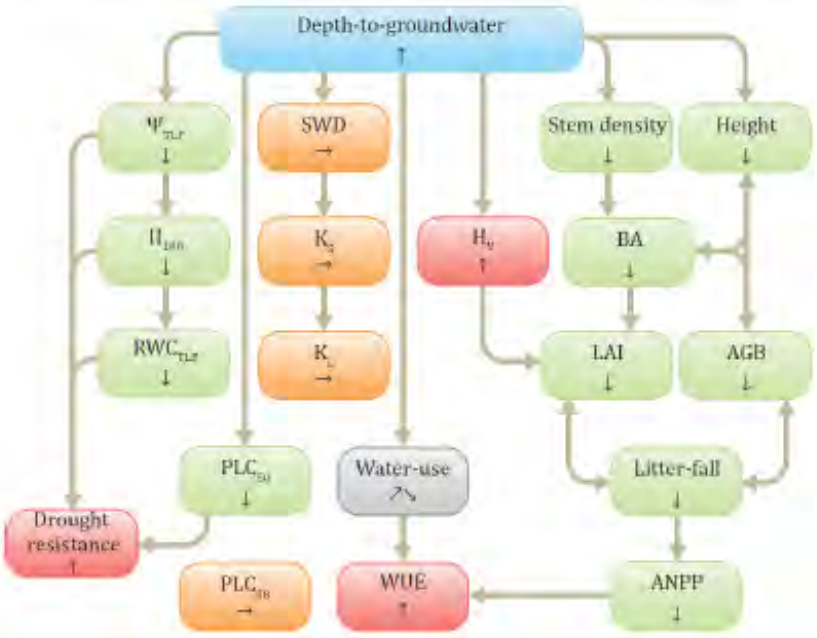


Figure 1.4 A summary of the traits examined and the general trend in response of those traits to increased depth-to-groundwater along a natural topographic gradient (reproduced from Eamus et al. 2015)

NB: Upward/downward pointing arrows within a coloured text box indicate increasing/decreasing values of the plant trait as depth-to-groundwater increases. Horizontal arrows indicate no change. Table (top) provides the definition of all abbreviations used in this figure.

1.4 Tree Water Status

Tree water status refers to the hydration status of the plant, which influences transpiration, photosynthesis and other key physiological functions. It is primarily determined by the physical conditions of the air and soil, between which the tree provides a hydraulic connection.

Plant water uptake operates on a diurnal cycle in synchrony with the solar radiation flux and associated plant photosynthesis, as schematically depicted in Figure 1.5Error! Reference source not found.. The transfer of water from the soil to the atmosphere necessarily requires that matric potential (i.e. a suction force) progressively increases from the soil to roots, stems, leaves and the atmosphere respectively. Of particular note:

- Leaf water potential (LWP) is recognised as a leading or 'real time' indicator of plant water status, and is a fundamental metric providing information on various ecophysiological processes (Novick et al. 2022). Measurements of predawn and midday LWP (Ψ) collected on the same day indicate the strength of hydraulic gradient developed within the xylem pathway of the tree to facilitate soil water uptake (i.e. midday Ψ_{leaf} – predawn Ψ_{leaf}). This differential, in combination with absolute values of LWP, can provide insights into source waters being accessed by trees.
- Predawn Ψ_{leaf} provides a proxy for the matric potential of wettest soil layer in the rooting zone under most conditions. Exceptions can occur where night-time transpiration is facilitated by abundant soil water and atmospheric demand, or there is insufficient time during the night for complete refilling of plant tissues (Kangur et al. 2021); in such cases predawn Ψ_{leaf} will be slightly more negative than soil Ψ. Notwithstanding, across multiple studies and growing conditions, typically the magnitude of disequilibrium is less than about 0.5 MPa (Kangur et al. 2021, Zeppel et al. 2010, Kavanagh et al. 2007, Donovan et al. 2001).
- Midday Ψ_{leaf} typically corresponds with the minimum (i.e. most negative) leaf water potential developed over the diurnal cycle. It is influenced by photosynthetically available radiation and atmospheric evaporative demand in addition to soil moisture. For a given species, stomatal closure regulation also controls minimum Ψ_{leaf}; strongly isohydric species will maintain minimum Ψ_{leaf} above a threshold value that effectively constitutes a hydraulic safety margin (see below).

Relationships between midday Ψ_{leaf} and predawn Ψ_{leaf} underpin the concept of Hydroscape Area, which is a species-specific metric defined as the area of the triangle formed when unconstrained[5] midday Ψ_{leaf} is plotted as a function of predawn Ψ_{leaf} (Figure 1.6, top). Soil saturation corresponds with predawn Ψ_{leaf} being close to zero, whilst the point predawn Ψ_{leaf} = midday Ψ_{leaf} indicates dry soil, stomatal closure and cessation of transpiration. Hydroscape Area provides an integrated measure water regulation and drought tolerance traits (Li et al. 2019). Larger hydroscape areas correlate with a lower (i.e. more negative) leaf turgor loss point[6], water potential inducing 90% loss of maximum stomal conductance, loss of conductivity in leaves at a given matric potential and mesophyll photosynthetic sensitivity to leaf water potential (Salvi et al. 2022; Fu and Meinzer 2019). Therefore, species with larger hydroscape areas exhibit greater drought tolerance (i.e. an ability to resist hydraulic failure at more negative matric potentials).

[5] Unconstrained midday Ψ_{leaf} refers to the situation where innate characteristics of the plant hydraulic pathway set the minimum Ψ_{leaf} value during the diurnal cycle (i.e. photosynthetically available radiation and atmospheric evaporative demand are not limiting).

[6] The matric potential at which leaves lose turgor. In most species this occurs before the point of hydraulic failure, which enables plant to rehydrate and recover from drought stress.

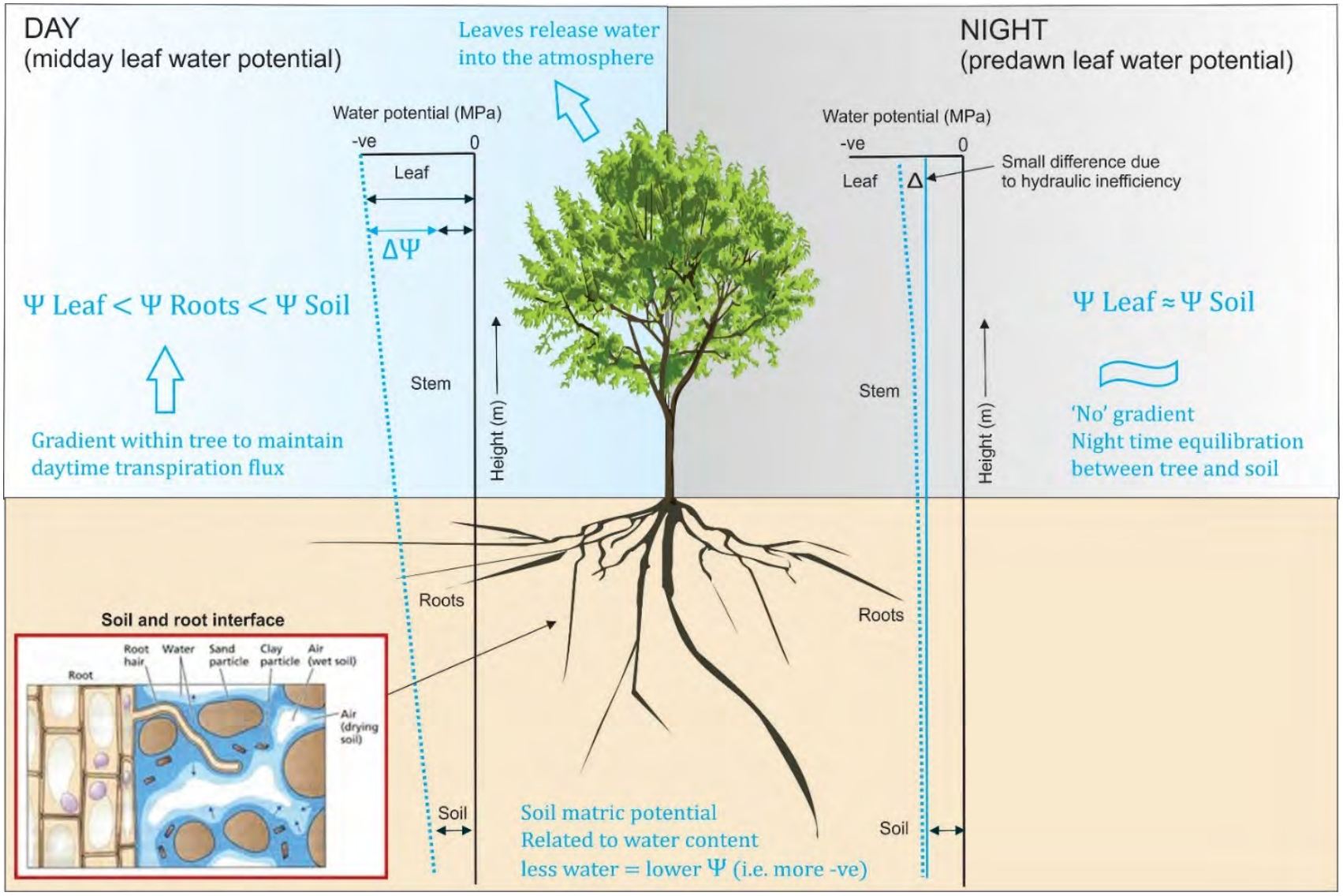


Figure 1.5 The diurnal cycle of matric potential gradients developed in plants

Related to hydroscape area, a widely used framework for classifying plant hydraulic strategies is the isohydric-anisohydric continuum (Meinzer et al. 2016; Fu and Meinzer 2019). Species with greater isohydry exhibit tight control of stomatal conductance and leaf water potential as Ψ_{soil} declines (refer to Figure 1.6). This prevents exposure to xylem embolism[7] and associated loss of conductivity in the plant hydraulic pathway; but also limits the ability of plants to maintain photosynthetic carbon fixation under dry conditions. In contrast, more anisohydric species tend to maintain stomatal conductance in response to drought, resulting in greater reductions in Ψ_{leaf} with declining Ψ_{soil}. This allows carbon fixation to be maintained under progressively drying conditions, but exposes plants to a higher risk of hydraulic failure. Smaller hydroscape area typically corresponds with a greater degree of isohydry. In the case of *Eucalyptus* species, anisohydric species exhibit greater drought-tolerance and tend to occupy environments with greater variability in precipitation and moisture availability (Salvi et al. 2022).

Recent studies have also highlighted the importance of atmospheric water demand on the relationship between Ψ_{leaf} and Ψ_{soil}, contributing to temporal variability in plant hydraulic strategies. This involves plants switching between isohydric and anisohydric responses within their hydroscapes. In general terms, three phases are elucidated based on progressive exposure to water stress (Kannenburg et al. 2022):

- Phase 1 (anisohydric): abundant water is associated with little stomatal control over midday Ψ_{leaf}. The hydraulic gradient is largely determined by, and fluctuates in response to, atmospheric evaporative demand. The upper limit ultimately set by the hydraulic limits of the xylem pathway from root to leaf.
- Phase 2 (isohydric): moderate dry downs, associated with tight stomatal control over midday Ψ_{leaf} when atmospheric evaporative demand increases.
- Phase 3 (anisohydric): large dry downs, associated with leaf turgor loss and declines in hydraulic conductivity. In some species, where dry downs are severe enough, steep declines in water potential during this phase could be due to transpiration cooling required to protect leaves from damaging thermal stress.

A schematic depiction of this progressive, non-linear water regulation behaviour is shown in Figure 1.7. Note the influence of atmospheric evaporative demand[8] during the different phases. Different species can be expected to have differing levels of 'isohydric/anisohydric rigidity' under varying hydrologic demands.

1.5 Ecological Rehydration Index

AQ2 has extended the hydroscape concept by defining an 'ecological rehydration index' (ERI), being the ratio of the hydraulic gradient developed at peak daily transpiration relative to minimum Ψ_{leaf} :

$$Ecological\ Rehydration\ Index\ (ERI) = \frac{(\text{midday } \Psi\text{leaf} - \text{ predawn } \Psi\text{leaf})}{\text{midday } \Psi\text{leaf}}$$

ERI values provide an integrated 'point' measurement of tree water status, with higher values reflecting a greater ability of the tree to maintain and maximise transpiration and photosynthesis. ERI values can be interpreted by plotting hydraulic gradient (midday Ψ_{leaf} – predawn Ψ_{leaf}) against predawn Ψ_{leaf} as shown in Figure 1.6.

[7] when the tension of water within the xylem becomes so high that dissolved air within the water expands to fill and effectively block the vessels.

[8] Expressed as vapour pressure deficit (VPD).

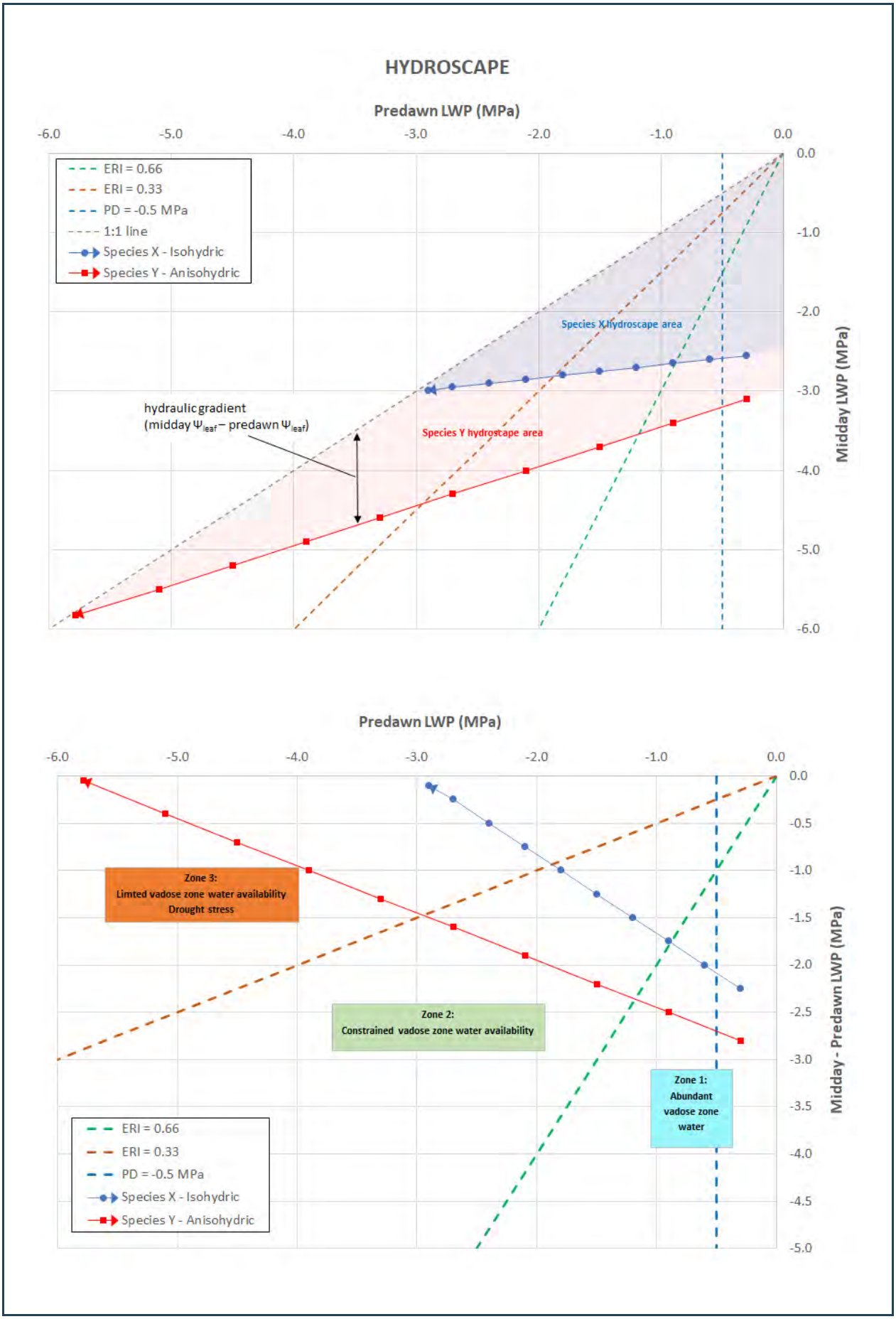


Figure 1.6 The Ecological Rehydration Index (ERI) Analytical Framework

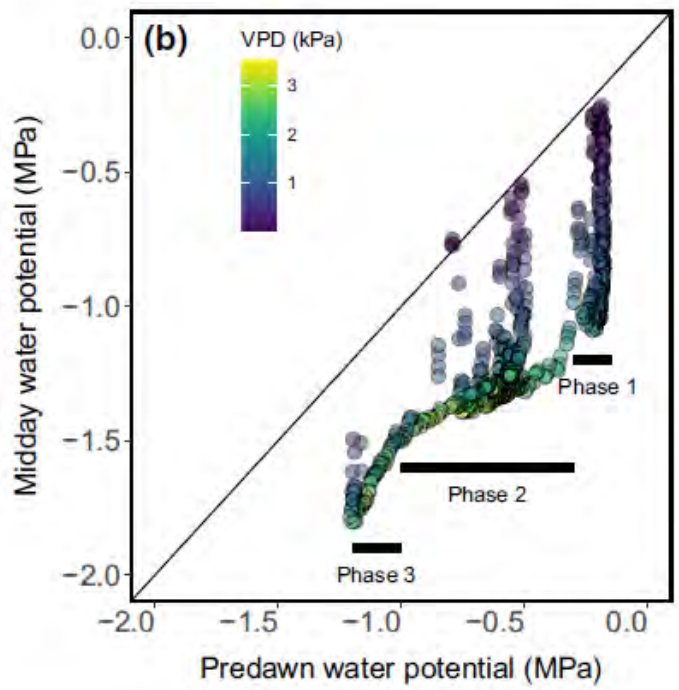


Figure 1.7 Conceptual model of phasic behaviour in the relationship between midday Ψleaf – predawn Ψ_{leaf} influenced by atmospheric evaporative demand (reproduced from Kannenburg et al. 2022)

Three ERI zones have been defined based on analysis of multiple datasets from Pilbara and other arid zone tree species:

- Zone 1: Abundant water availability; characterised by high levels of rehydration (ERI > ≈0.66) and relatively high (i.e. close to zero) predawn Ψ_{leaf} values. Trees operating in this zone have access to moist to very moist vadose soil layers and/or groundwater; the latter typically where predawn Ψ_{leaf} is close to zero assuming low water salinity and relatively shallow groundwater depth (<10 m). Corresponds with high rates of transpiration, photosynthesis and growth.
- Zone 2: Constrained water availability; characterised by moderate levels of rehydration (ERI between about 0.33 and 0.66). Trees operating in this zone have access to variably moist soil layers, but transpiration and photosynthesis is constrained by available soil moisture.
- Zone 3: Impaired root water uptake; characterised by low levels of rehydration (< ≈0.33). Trees operating in this zone are subject to pronounced water stress. Most commonly this is associated with dry soil and drought stress; however it may also be attributable to poorly functioning root systems (for example due to waterlogging or salinity).

In the case of trees operating in Zone 1, further investigation of site-specific factors (e.g. soil profile characteristics, depth to groundwater, tree species and age) is necessary to determine whether or not trees are accessing groundwater or deep vadose storage. For a given tree species, conclusions about groundwater use for should ideally be based on a time series of LWP measurements spanning a range of seasonal conditions, in combination with consideration of vegetation growth patterns and site water balance. This can enable differentiation between the progressive depletion of deep, vadose soil water stores and perennial (or transient) access to groundwater. When only single point measurement data is available, predawn Ψ_{leaf} values greater (i.e. less negative) than approximately -0.50 MPa provide an indication of potential groundwater use by trees.

APPENDIX M
SOIL ANALYSIS & PSD REPORTS

Analysis Results

CSBP Soil and Plant Laboratory

94444
Equinox Environmental Pty Ltd

	Lab No	8SS23175	8SS23176	8SS23177	8SS23178	8SS23179	8SS23180	8SS23181	8SS23182
	Name	Topsoil1 - A	Topsoil2 - B	Topsoil3-C	Crust - D1	Below-crust-D2	Topsoil4-E	Topsoil5-F	Topsoil6-G
	Code	EQU1	EQU2	EQU3	EQU4	EQU5	EQU6	EQU7	EQU8
	Customer	Equinox Environmental Pty Ltd	Equinox Environmental Pty Ltd	Equinox Environmental Pty Ltd	Equinox Environmental Pty Ltd	Equinox Environmental Pty Ltd	Equinox Environmental Pty Ltd	Equinox Environmental Pty Ltd	Equinox Environmental Pty Ltd
	Depth	0-10	0-10	0-10	0-10	0-10	0-10	0-10	0-10
Chloride	mg/kg	6.8	105.6	2.4	29.3	1861.5	10.3	26.8	10.2
ECe	dS/m	0.38	1.11	0.13	0.65	11.93	0.57	0.38	0.22
Saturation Paste exch. Ca	meq/L	1.63	1.22	0.11	1.25	12.86	2.56	2.36	0.77
Saturation Paste exch. K	meq/L	0.09	0.89	0.50	1.74	0.81	0.35	3.33	0.67
Saturation Paste exch. Mg	meq/L	0.46	0.66	0.32	4.32	4.33	0.60	9.31	1.66
Saturation Paste exch. Na	meq/L	0.29	5.46	0.29	4.49	87.98	0.81	1.96	0.74
Saturation Paste %	%	61.85	61.02	56.33	51.99	71.13	80.77	69.27	67.04
MCP Sulfur	mg/kg	3.1	11.3	6.1	4.2	295.0	9.2	5.4	8.4
Moisture %	%	7.43	4.28	2.92	3.34	6.81	9.02	33.02	42.43

CSBP Lab. Extract Value.

Analysis Results

CSBP Soil and Plant Laboratory

	Lab No	8SS23183
	Name	Topsoil7-H
	Code	EQU9
	Customer	Equinox Environmental Pty Ltd
	Depth	0-10
Chloride	mg/kg	3.6
ECe	dS/m	0.07
Saturation Paste exch. Ca	meq/L	0.17
Saturation Paste exch. K	meq/L	0.13
Saturation Paste exch. Mg	meq/L	0.11
Saturation Paste exch. Na	meq/L	0.11
Saturation Paste %	%	81.51
MCP Sulfur	mg/kg	7.7
Moisture %	%	2.38

CSBP Lab. Extract Value.

Perth
Unit 3, 34 Sphinx Way
Bibra Lake
WA 6163
Ph: (08) 9418 8742
E-mail: Phillip.li@eprecisionlab.com
Mob: 0422 814 231

Sample No: MDPZ7449

E-Precision Laboratory

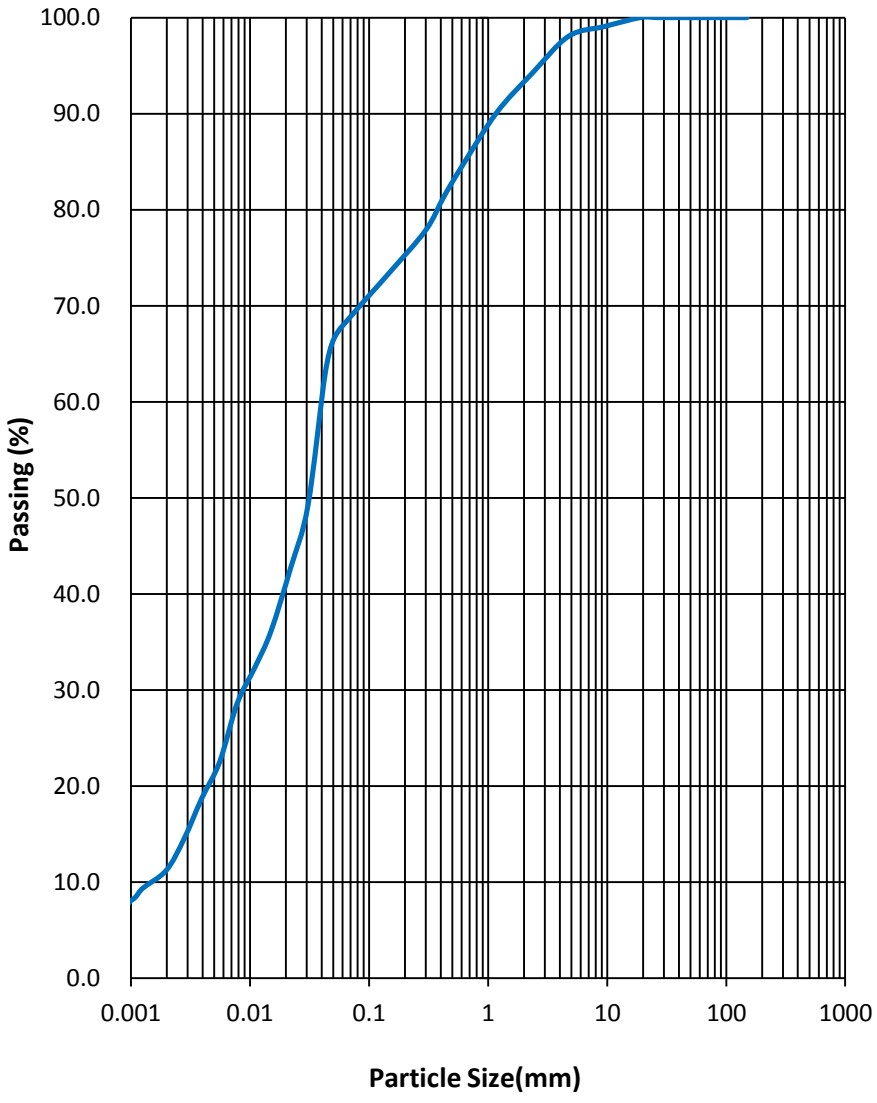
PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1

Client:	AQ2	Date Tested:	08/03/2019
Project:	Mulga Downs	EP Lab Job Number:	AQ2
Sample No:	MDP27449 Sample 1	Depth(m):	2
Lab ID:	MDP27449_01_PSD	Room Temperature at Test:	19°C
Tested by:	Michael	2.36mm Particle Density (t/m³):	2.93
Checked by:	Phil		

Sieve Size (mm)	Passing %
150	100.0
75	100.0
53	100.0
37.5	100.0
26.5	100.0
19	100.0
9.5	99.1
4.75	98.1
2.36	94.2
1.18	90.1
0.6	84.5
0.425	81.3
0.3	77.9
0.15	73.5
0.075	69.3
0.05087	66.6
0.04276	62.8
0.03077	49.2
0.02194	42.7
0.01502	36.1
0.01102	32.4
0.00782	28.6
0.00557	22.5
0.00395	18.8
0.00281	14.5
0.00199	11.3
0.00126	9.4
0.00110	8.4
0.00098	8.0
0.00093	7.5

PSD Graph



Notes:
Stored and Tested the Sample as received
Samples supplied by the Client

NATA: 19078

Authorized Signature:

The results of tests performed apply only to the specific sample at time of test unless otherwise clearly stated. Reference should be made to E-Precision Laboratory's "Standard Terms and Conditions" E-Precision Laboratory ABN 431 559 578 87

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E-mail: Phillip.li@eprecisionlab.com
Mob: 0422 814 231

Sample No: MDPZ7449

E-Precision Laboratory

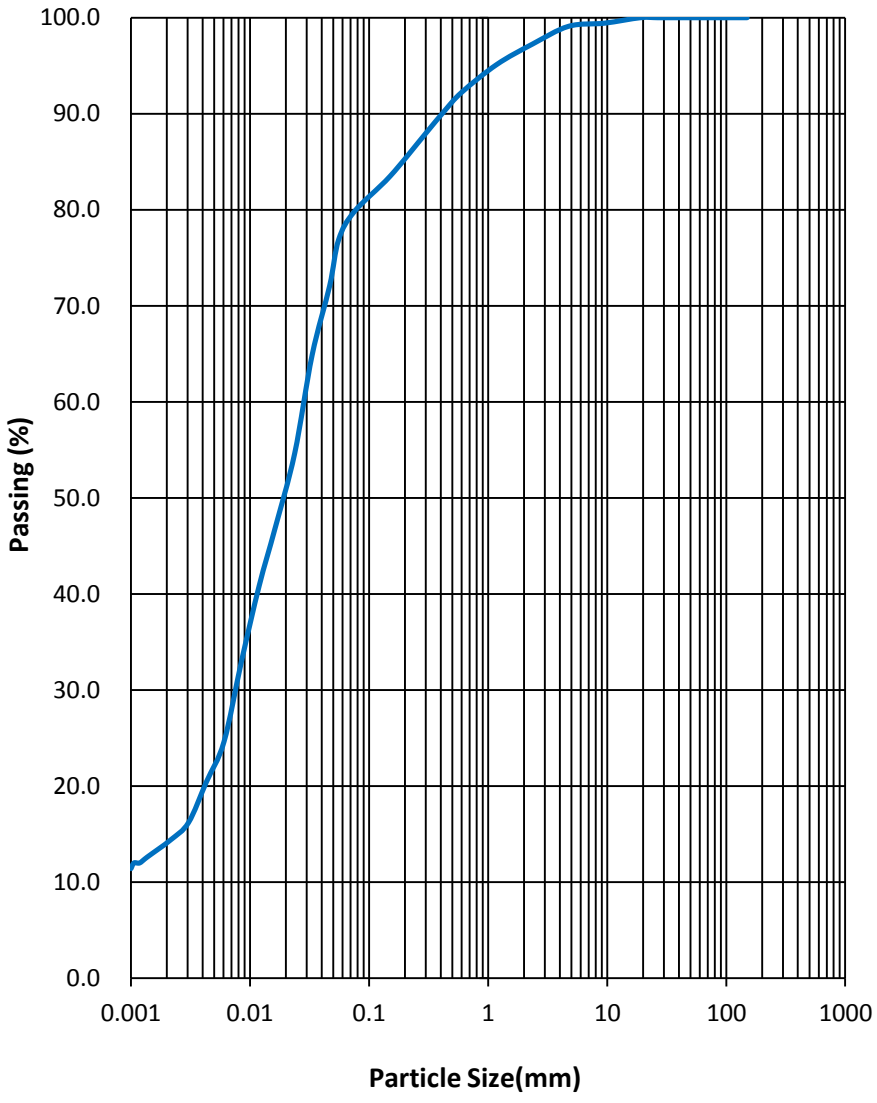
PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1

Client:	AQ2	Date Tested:	08/03/2019
Project:	Mulga Downs	EP Lab Job Number:	AQ2
Sample No:	MDP27449 Sample 2	Depth(m):	2
Lab ID:	MDP27449_02_PSD	Room Temperature at Test:	19°C
Tested by:	Michael	2.36mm Particle Density (t/m³):	2.65
Checked by:	Phil		

Sieve Size (mm)	Passing %
150	100.0
75	100.0
53	100.0
37.5	100.0
26.5	100.0
19	100.0
9.5	99.4
4.75	99.1
2.36	97.3
1.18	95.1
0.6	92.2
0.425	90.2
0.3	88.0
0.15	83.5
0.075	79.8
0.05543	76.9
0.04660	72.1
0.03319	64.9
0.02371	54.7
0.01622	46.8
0.01191	40.8
0.00848	33.0
0.00604	24.6
0.00429	20.4
0.00304	16.2
0.00215	14.4
0.00137	12.6
0.00118	12.0
0.00106	12.0
0.00100	11.4

PSD Graph



Notes:
Stored and Tested the Sample as received
Samples supplied by the Client

NATA: 19078

Authorized Signature:

The results of tests performed apply only to the specific sample at time of test unless otherwise clearly stated. Reference should be made to E-Precision Laboratory's "Standard Terms and Conditions" E-Precision Laboratory ABN 431 559 578 87

Perth
Unit 3, 34 Sphinx Way
Bibra Lake
WA 6163
Ph: (08) 9418 8742
E-mail: Phillip.li@eprecisionlab.com
Mob: 0422 814 231

Sample No: MDPZ7451

E-Precision Laboratory

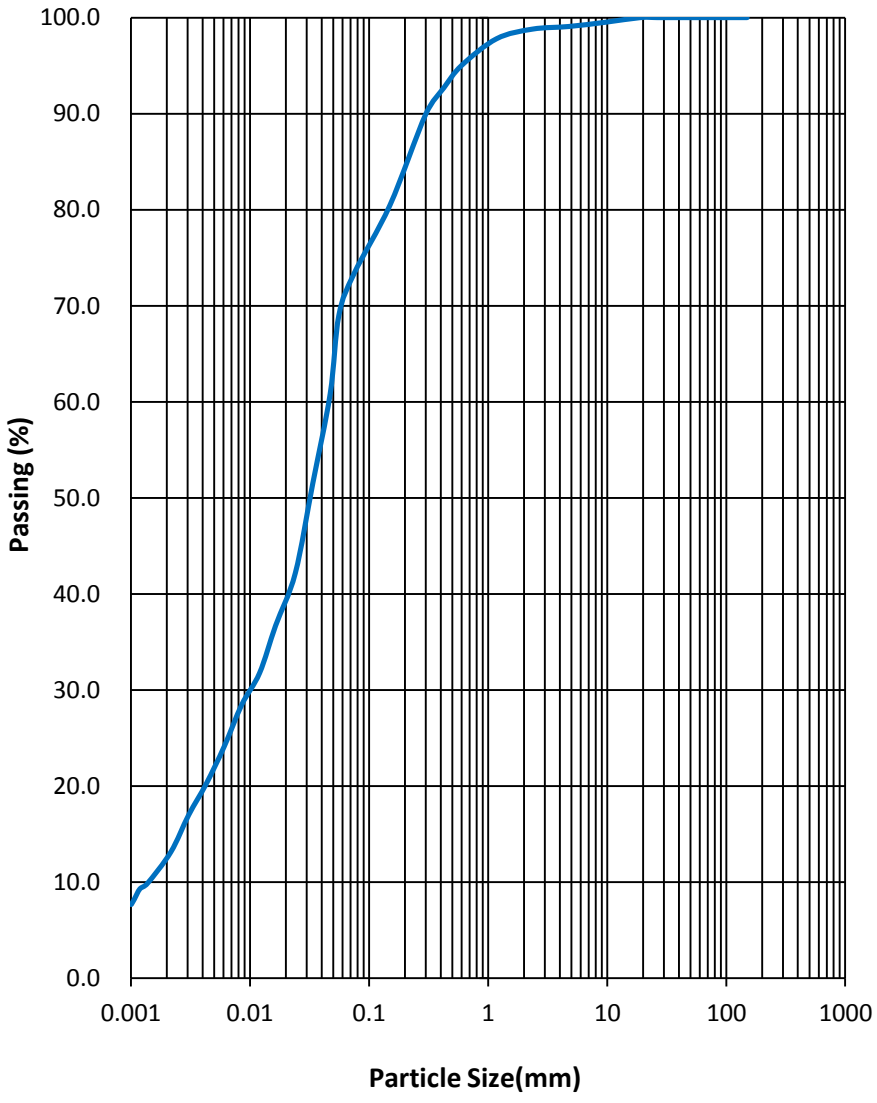
PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1

Client:	AQ2	Date Tested:	08/03/2019
Project:	Mulga Downs	EP Lab Job Number:	AQ2
Sample No:	MDP27451 Sample 3	Depth(m):	2
Lab ID:	MDP27451_03_PSD	Room Temperature at Test:	19°C
Tested by:	Michael	2.36mm Particle Density (t/m³):	2.63
Checked by:	Phil		

Sieve Size (mm)	Passing %
150	100.0
75	100.0
53	100.0
37.5	100.0
26.5	100.0
19	100.0
9.5	99.5
4.75	99.1
2.36	98.8
1.18	97.8
0.6	95.0
0.425	92.7
0.3	90.0
0.15	80.5
0.075	73.4
0.05584	69.0
0.04714	60.8
0.03368	51.5
0.02405	42.2
0.01642	36.7
0.01205	31.8
0.00855	28.5
0.00607	24.1
0.00431	20.3
0.00305	17.0
0.00217	13.1
0.00138	9.9
0.00119	9.3
0.00107	8.2
0.00101	7.7

PSD Graph



Notes:
Stored and Tested the Sample as received
Samples supplied by the Client

NATA: 19078

Authorized Signature:

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Sample No: MDPZ7452

E-Precision Laboratory

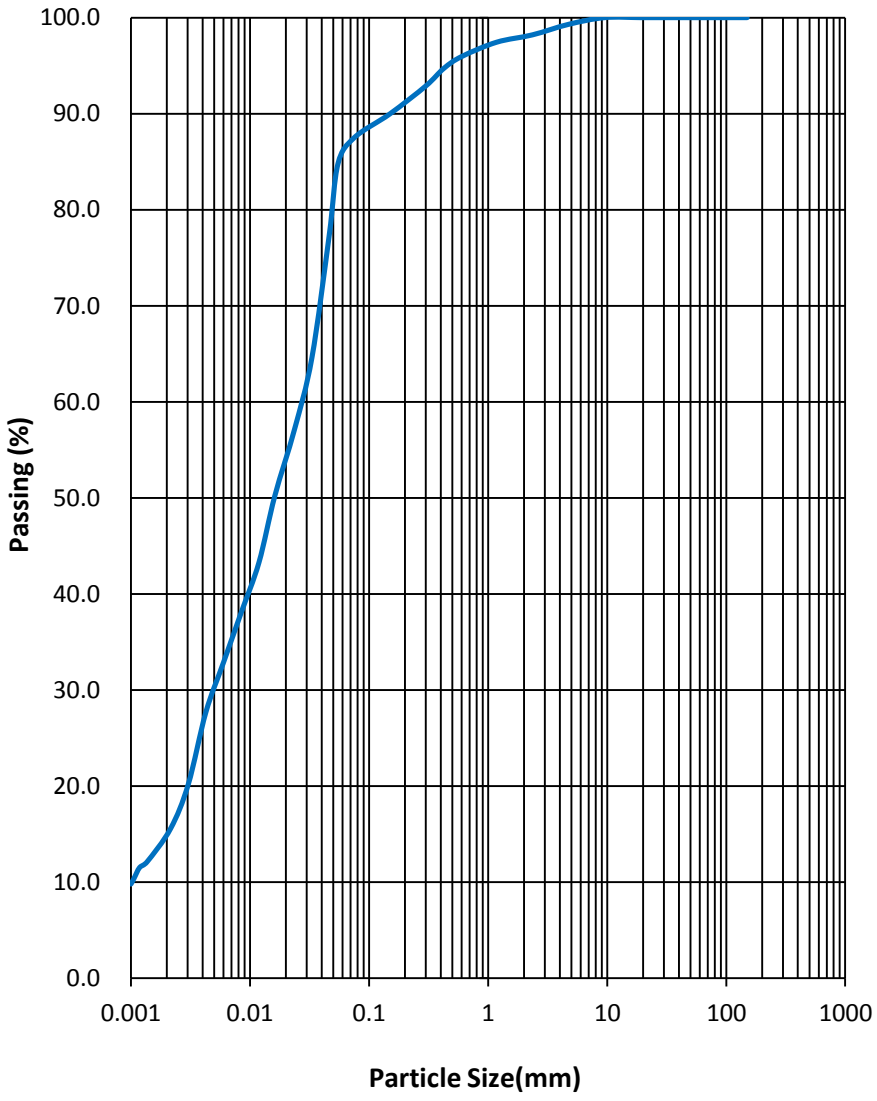
PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1

Client:	AQ2	Date Tested:	08/03/2019
Project:	Mulga Downs	EP Lab Job Number:	AQ2
Sample No:	MDP27452 Sample 4	Depth(m):	2
Lab ID:	MDP27452_04_PSD	Room Temperature at Test:	19°C
Tested by:	Michael	2.36mm Particle Density (t/m³):	2.64
Checked by:	Phil		

Sieve Size (mm)	Passing %
150	100.0
75	100.0
53	100.0
37.5	100.0
26.5	100.0
19	100.0
9.5	100.0
4.75	99.3
2.36	98.2
1.18	97.4
0.6	95.9
0.425	94.7
0.3	92.9
0.15	90.0
0.075	87.5
0.05490	84.8
0.04629	77.3
0.03317	64.6
0.02364	57.1
0.01616	50.2
0.01189	43.3
0.00845	38.1
0.00600	32.9
0.00426	27.7
0.00303	20.2
0.00215	15.6
0.00137	12.1
0.00118	11.5
0.00106	10.4
0.00100	9.8

PSD Graph



Notes:
Stored and Tested the Sample as received
Samples supplied by the Client

NATA: 19078

Authorized Signature:

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Sample No: MDPZ7459

E-Precision Laboratory

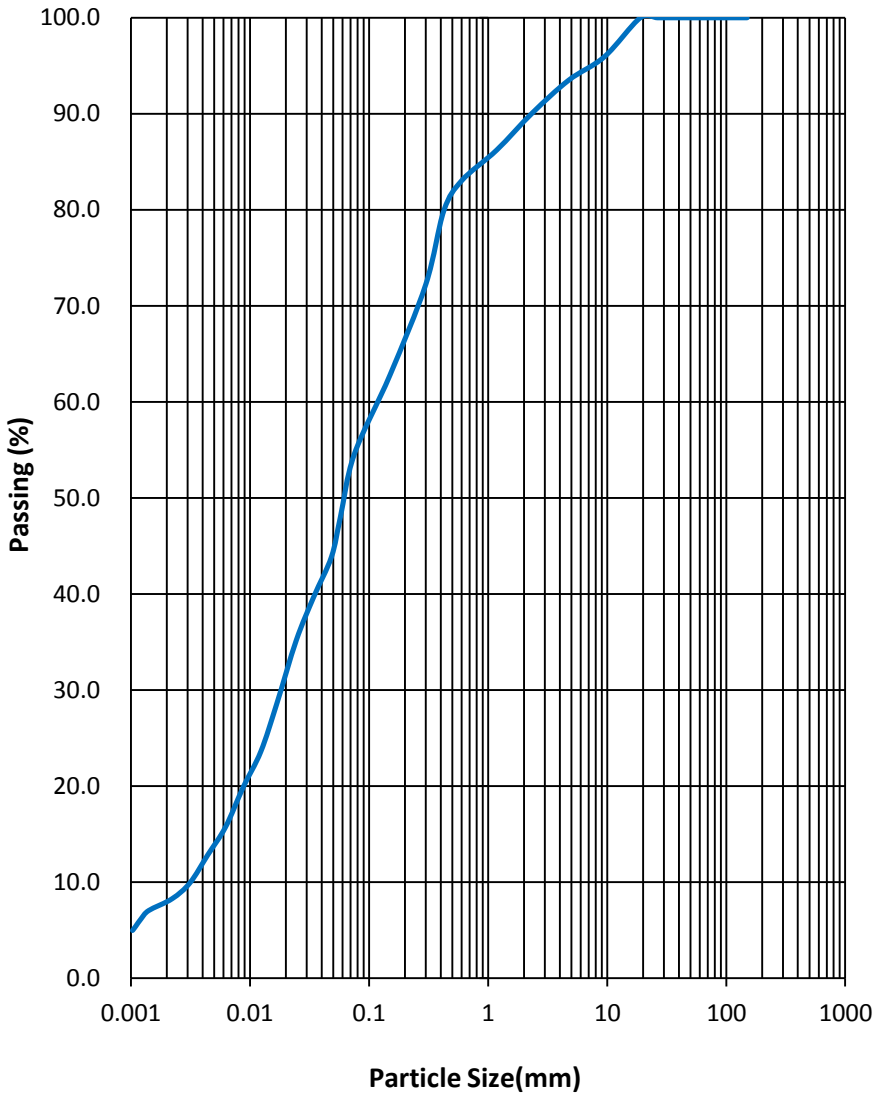
PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1

Client:	AQ2	Date Tested:	08/03/2019
Project:	Mulga Downs	EP Lab Job Number:	AQ2
Sample No:	AFMB01 Sample 5	Depth(m):	2
Lab ID:	AFMB01_05_PSD	Room Temperature at Test:	19°C
Tested by:	Michael	2.36mm Particle Density (t/m³):	2.56
Checked by:	Phil		

Sieve Size (mm)	Passing %
150	100.0
75	100.0
53	100.0
37.5	100.0
26.5	100.0
19	100.0
9.5	95.9
4.75	93.5
2.36	90.1
1.18	86.2
0.6	83.0
0.425	79.9
0.3	72.3
0.15	62.8
0.075	54.5
0.05741	48.0
0.04832	43.9
0.03437	39.7
0.02446	35.2
0.01676	28.6
0.01232	23.6
0.00875	19.9
0.00622	15.7
0.00441	12.8
0.00313	9.9
0.00222	8.3
0.00141	7.0
0.00122	6.2
0.00109	5.4
0.00103	5.0

PSD Graph



Notes:
Stored and Tested the Sample as received
Samples supplied by the Client

NATA: 19078

Authorized Signature:

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APPENDIX N
PHOTOGRAPHIC EXAMPLES OF LANDSCPE ECOHYDROLOGICAL UNITS

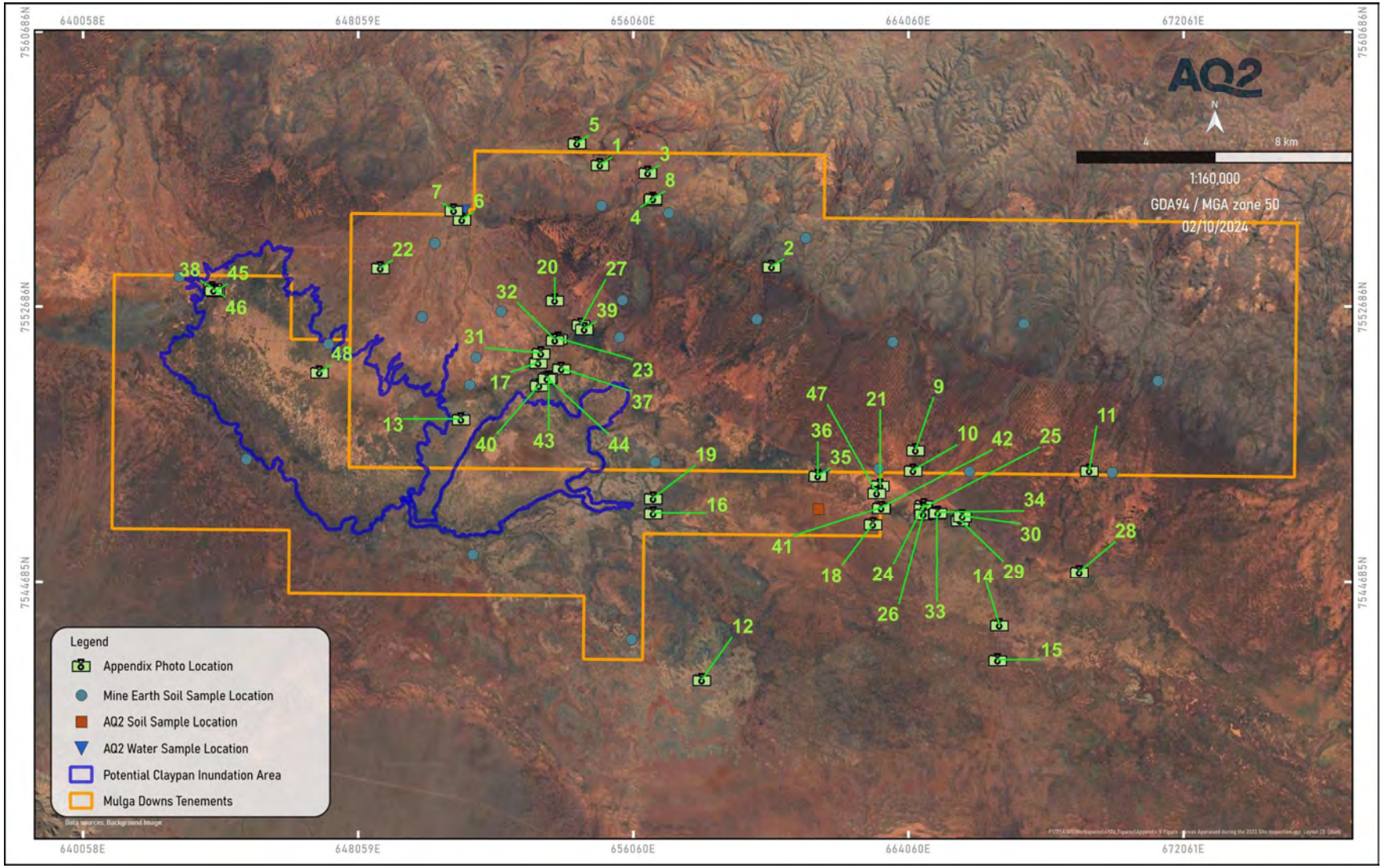
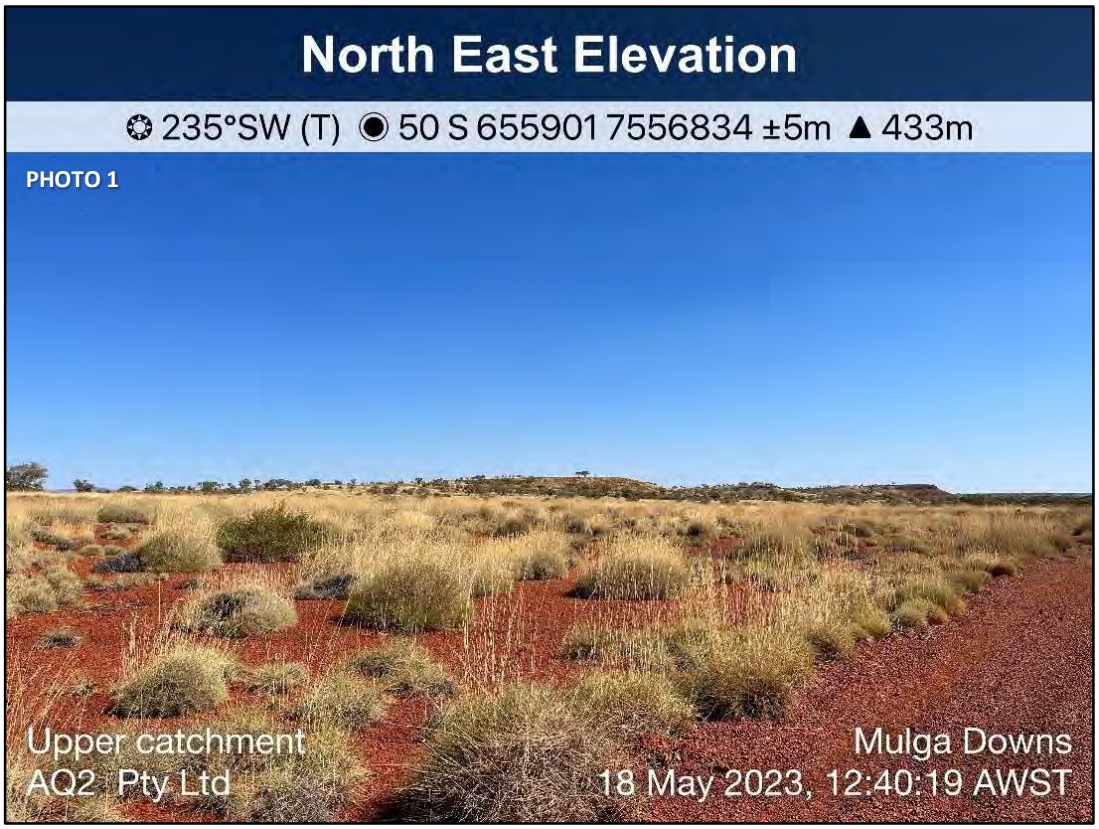
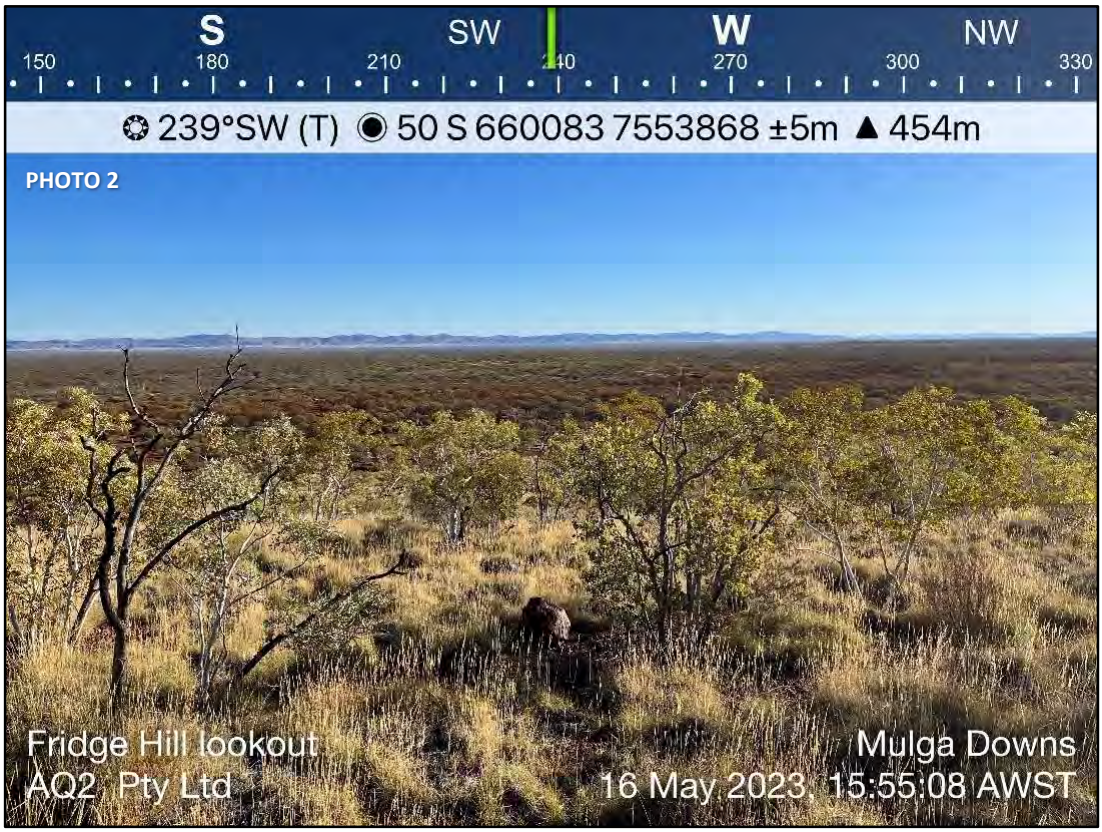


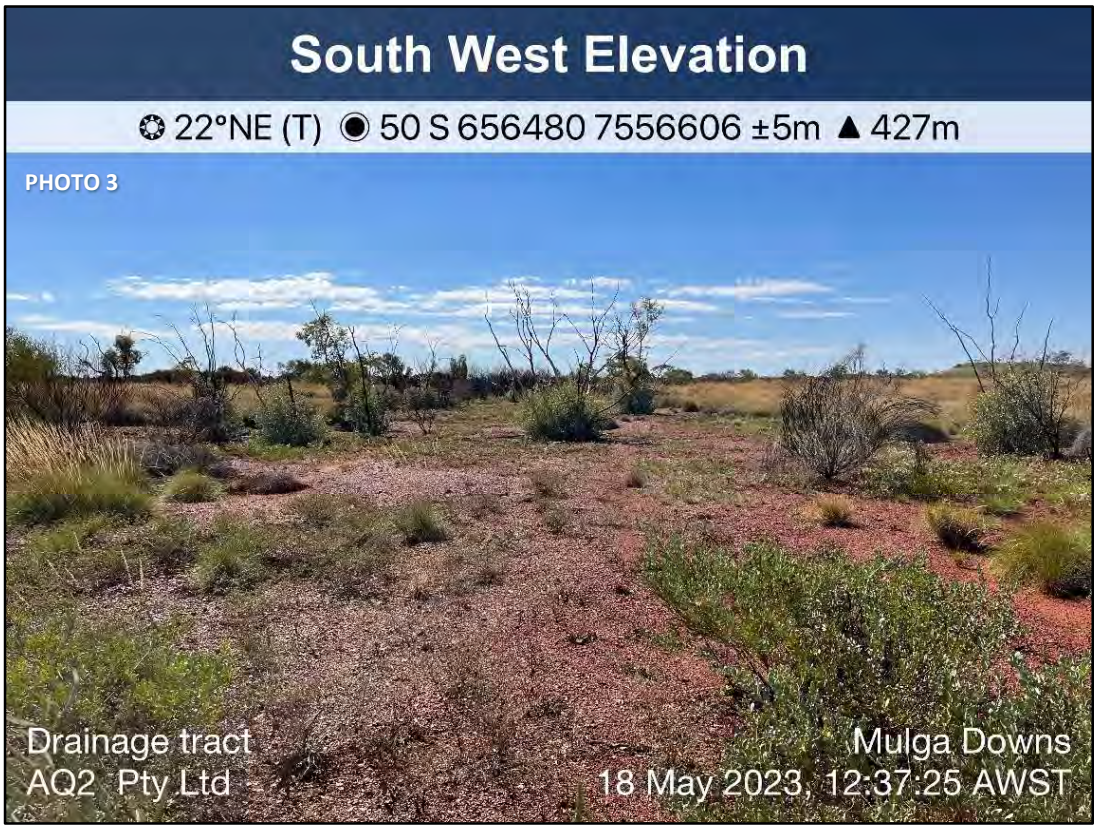
Figure 1 **Photographic Example Locations**

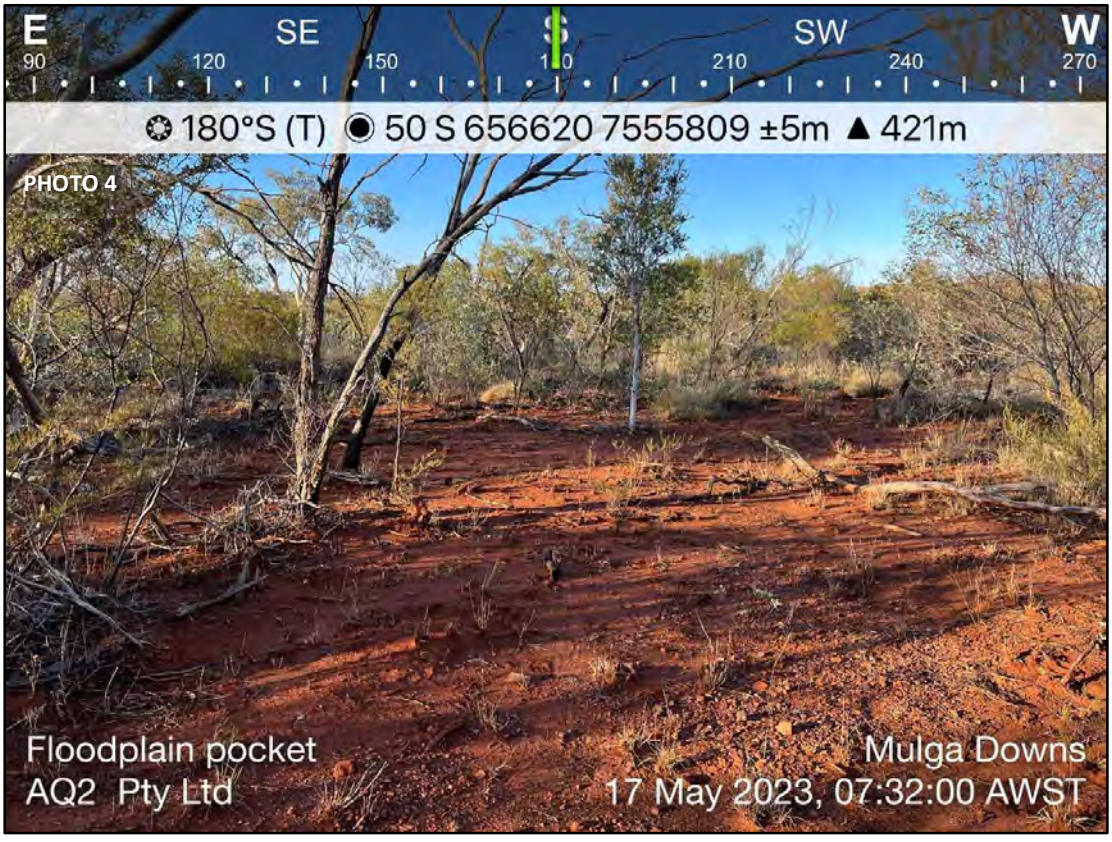
Example Photographs – Uplands



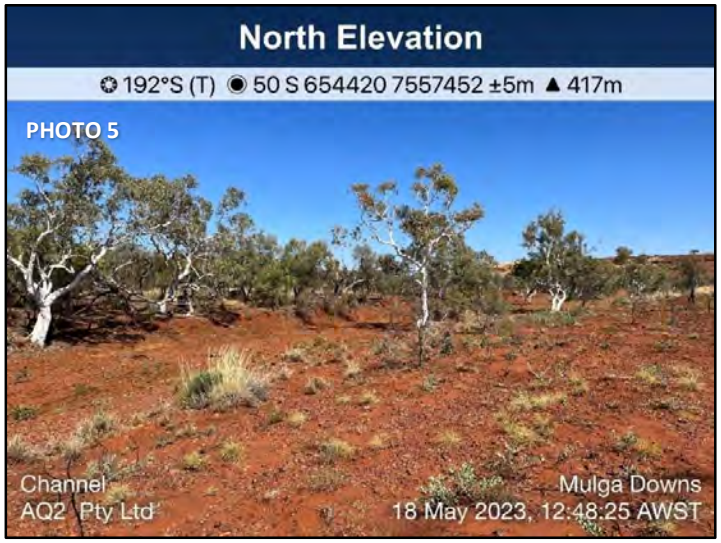


Example Photographs – Upland Valleys

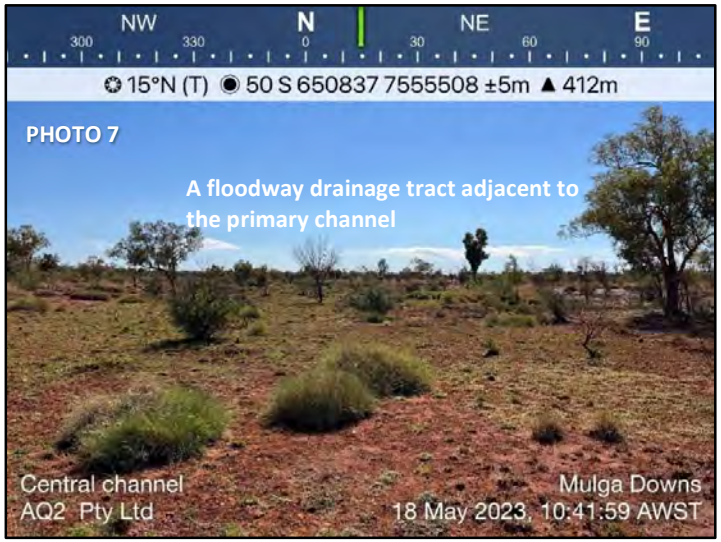


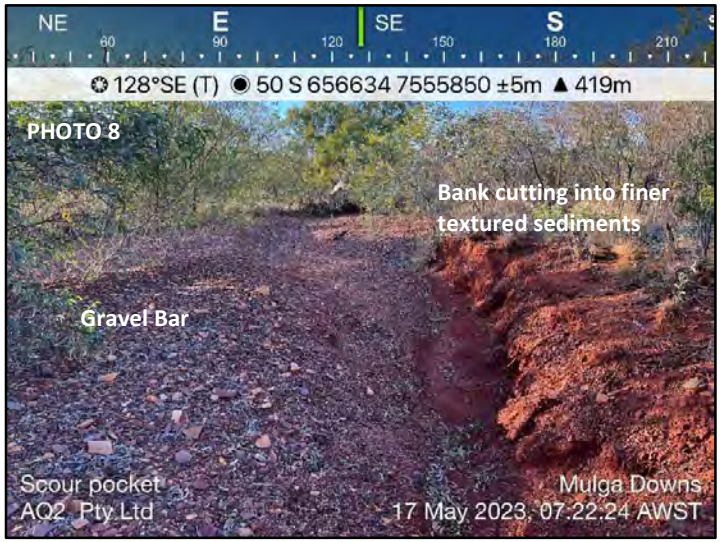


Example Photographs – Upland Drainages

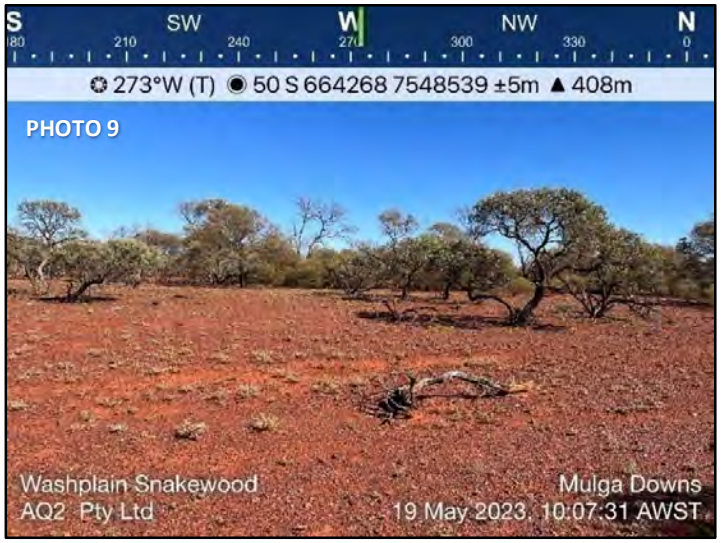


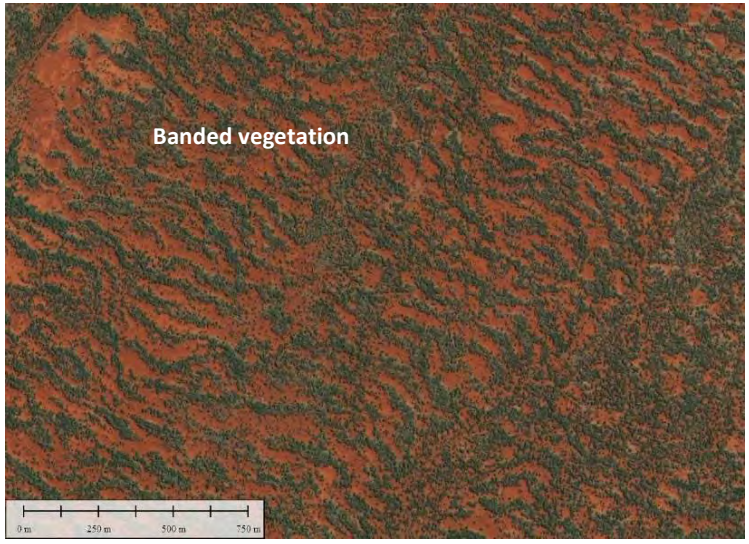


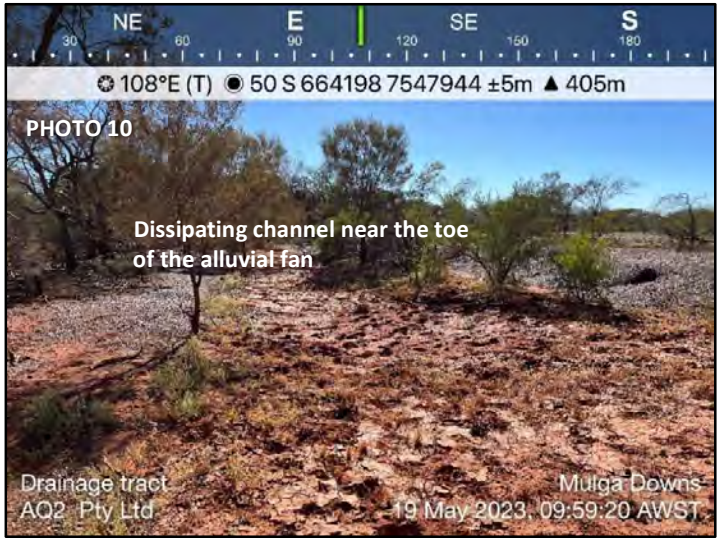


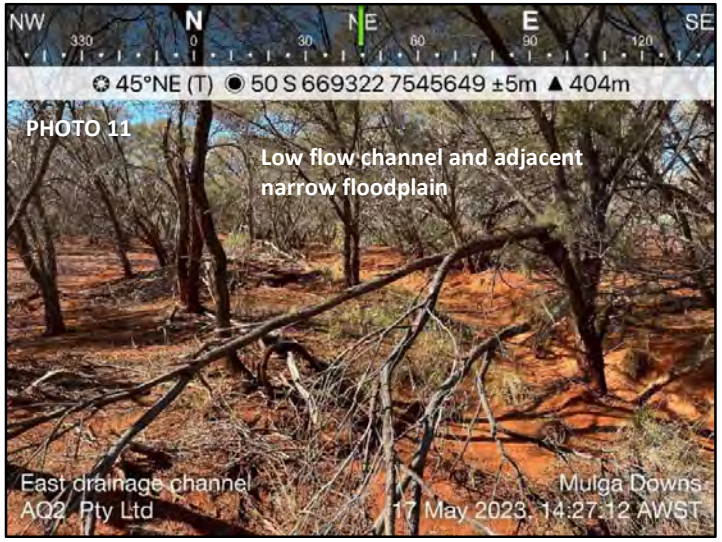


Example Photographs – Alluvial Fan





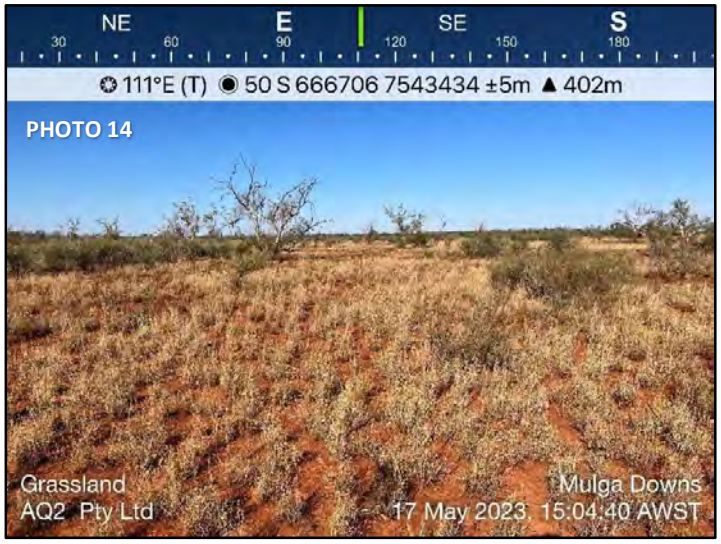


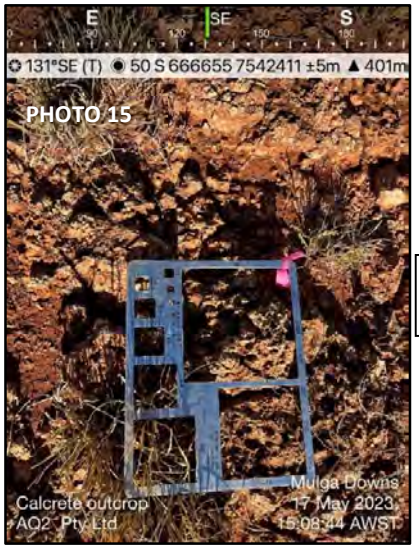


Example Photographs – Calcrete Flats and Rises



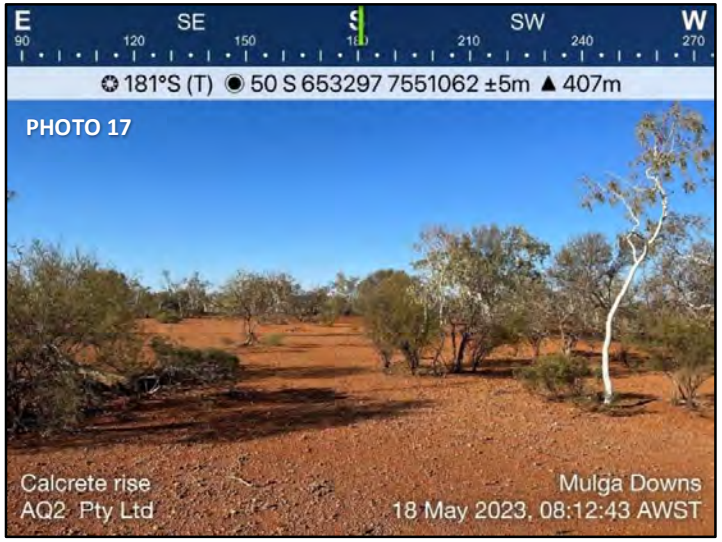


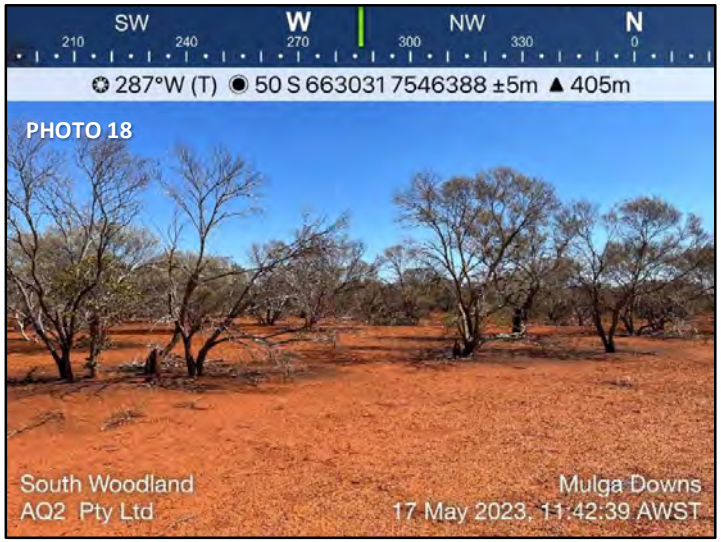


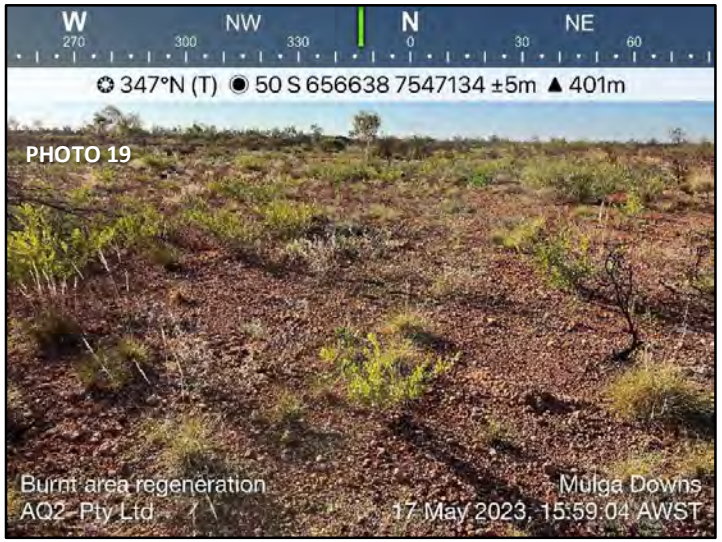


Weathered calcrete outcropping at surface

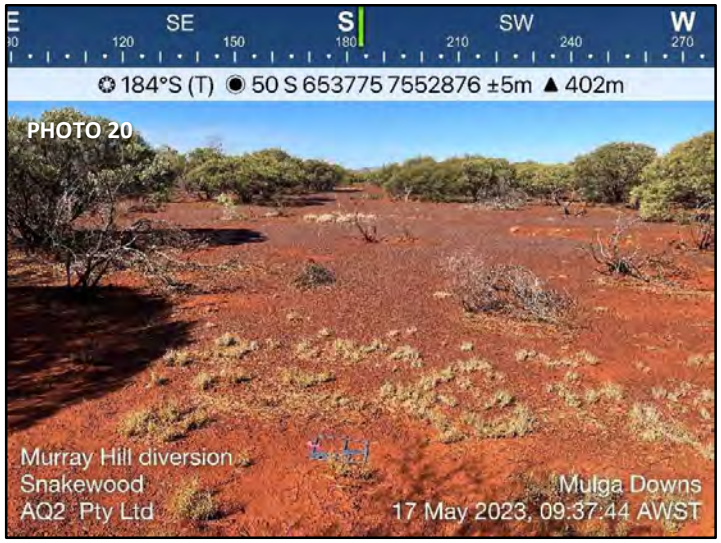

S 180 SW 210 240 W 270 300 NW 330
249°W (T) 50 S 656639 7546703 ±5m 400m
PHOTO 16
Calcrete incision drainage
AQ2 Pty Ltd
Mulga Downs
17 May 2023, 15:54:41 AWST

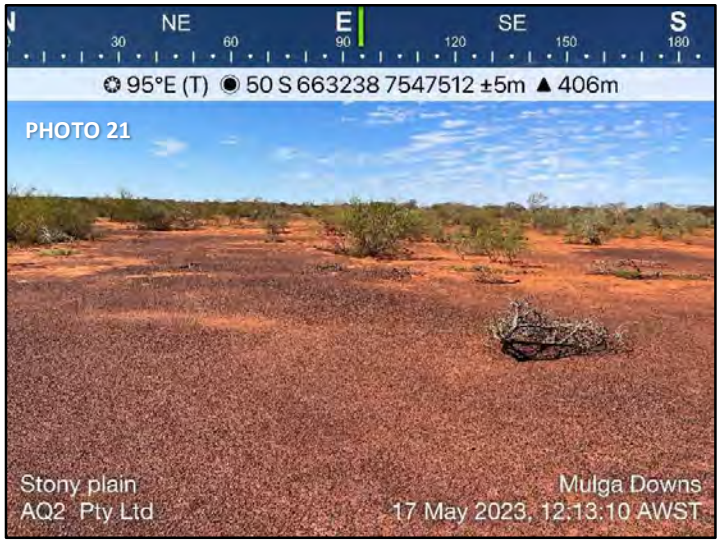

E 90 SE 120 150 S 180 210 SW 240 W 270
181°S (T) 50 S 653297 7551062 ±5m 407m
PHOTO 17
Calcrete rise
AQ2 Pty Ltd
Mulga Downs
18 May 2023, 08:12:43 AWST

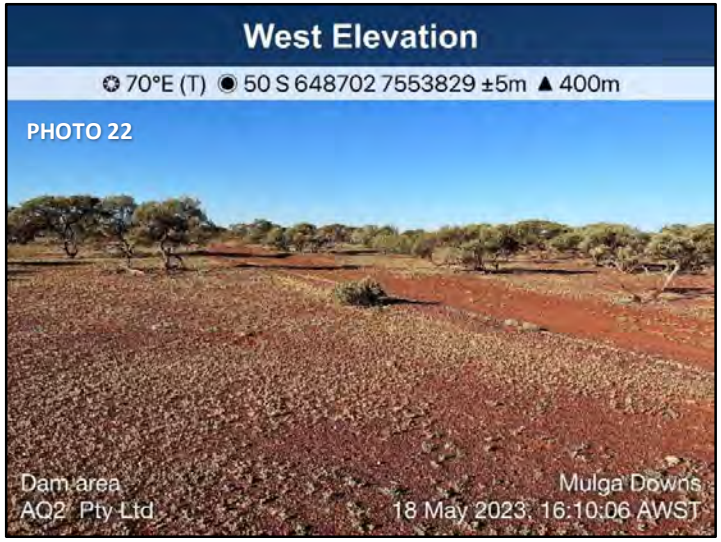

SW 210 240 W 270 NW 300 330 N 0
287°W (T) 50 S 663031 7546388 ±5m 405m
PHOTO 18
South Woodland
AQ2 Pty Ltd
Mulga Downs
17 May 2023, 11:42:39 AWST


W 270 NW 300 330 N 0 30 NE 60
347°N (T) 50 S 656638 7547134 ±5m 401m
PHOTO 19
Burnt area regeneration
AQ2 Pty Ltd
Mulga Downs
17 May 2023, 15:59:04 AWST

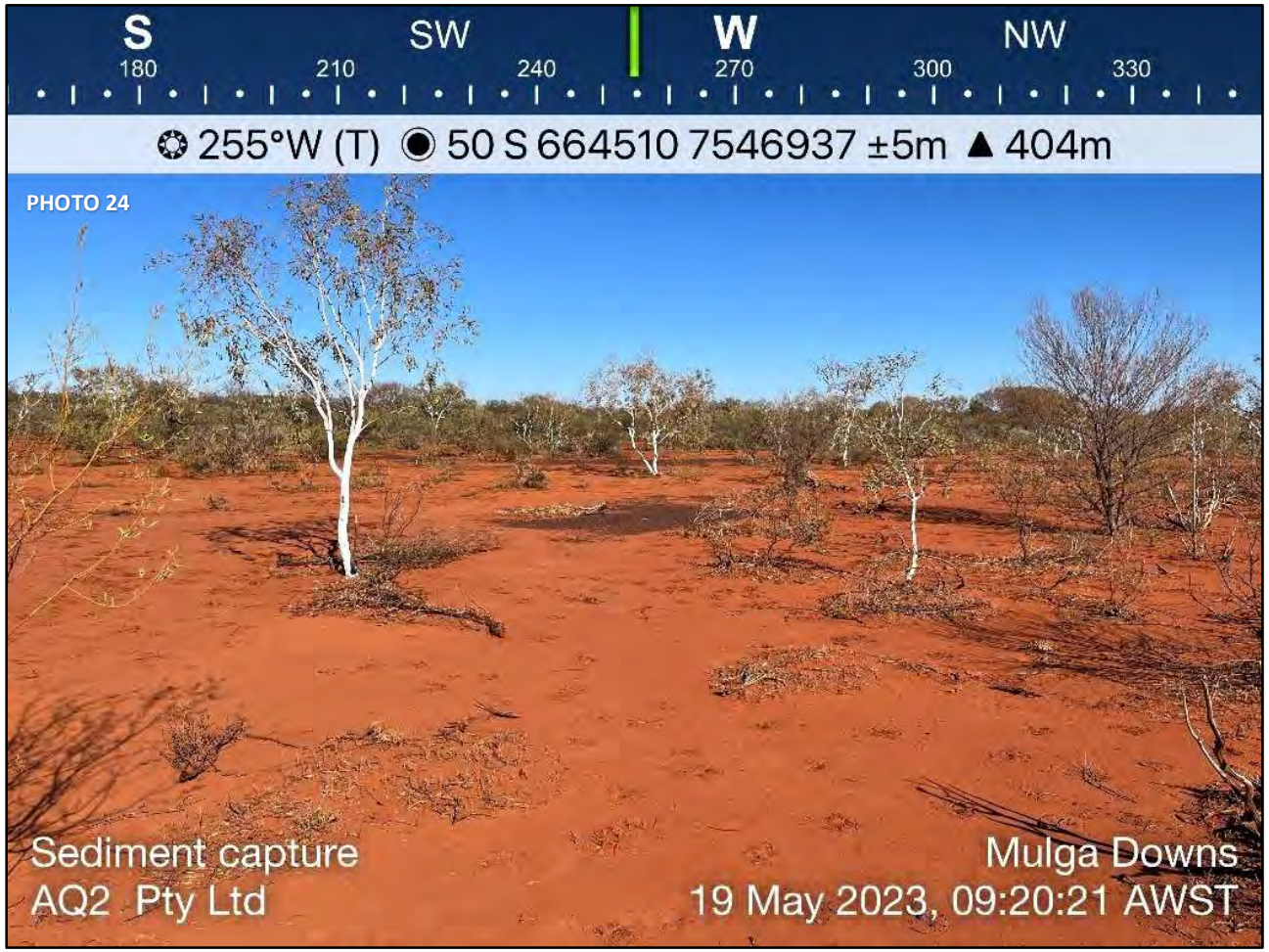
Example Photographs – Stony Flats





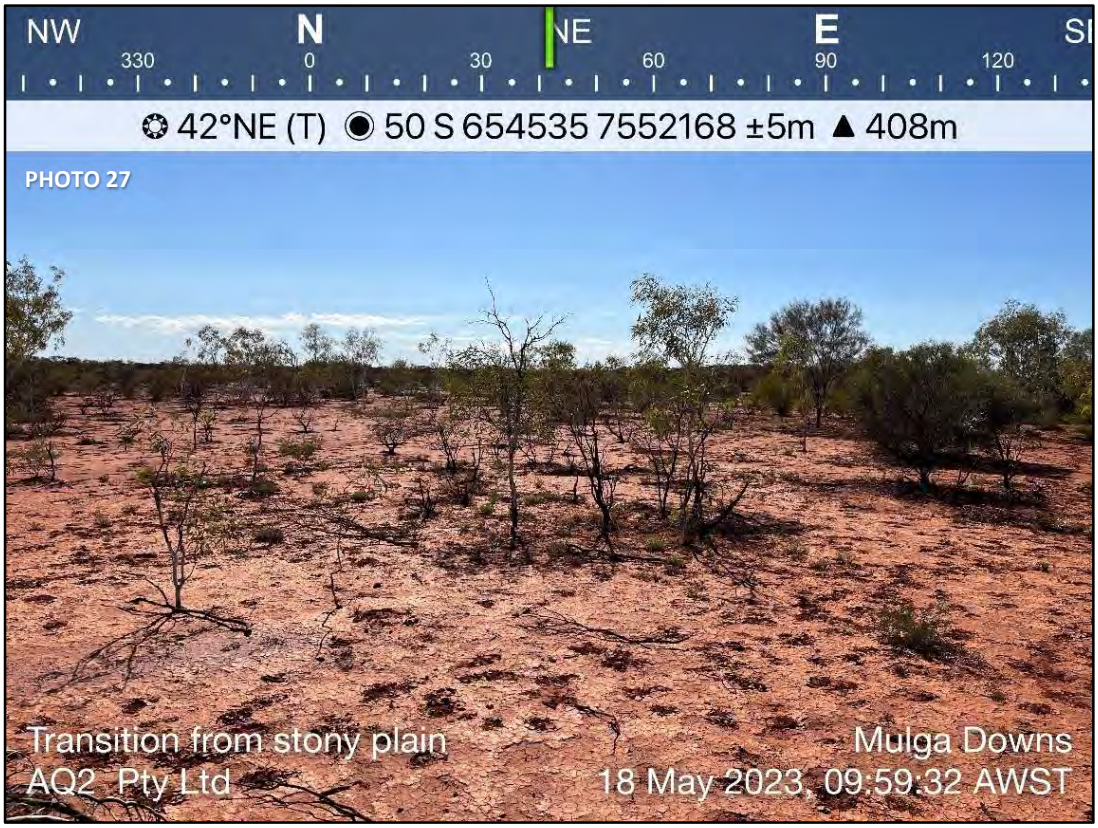


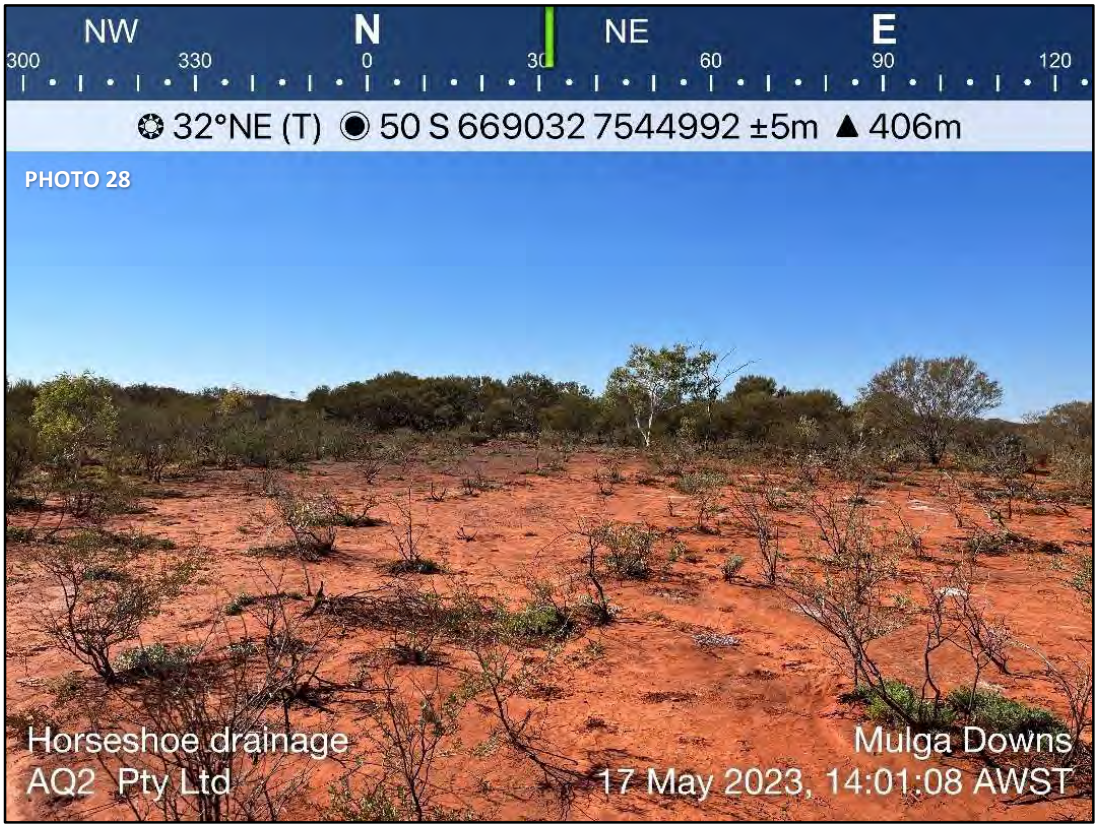



S
SW
W
NW
180
210
240
270
300
330
255°W (T) 50 S 664510 7546937 ±5m ▲ 404m
PHOTO 24
Sediment capture
AQ2 Pty Ltd
Mulga Downs
19 May 2023, 09:20:21 AWST

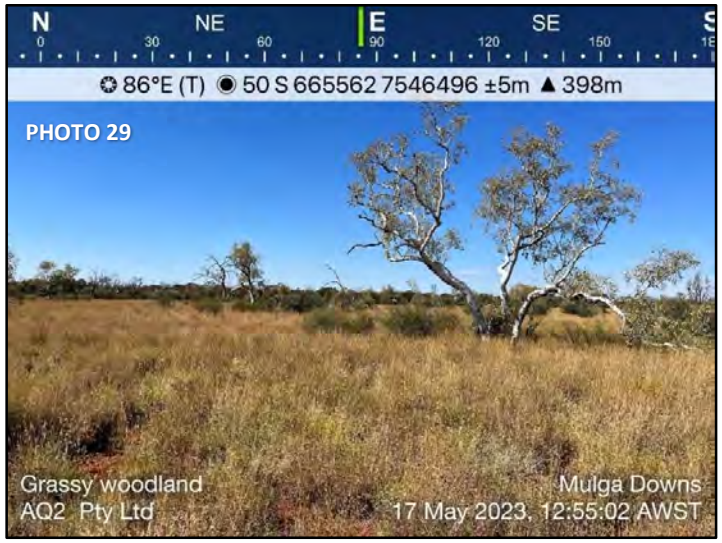

NE
E
SE
83°E (T) 50 S 664484 7546843 ±5m ▲ 403m
PHOTO 25
Local basin
AQ2 Pty Ltd
Mulga Downs
19 May 2023,
09:22:10 AWST

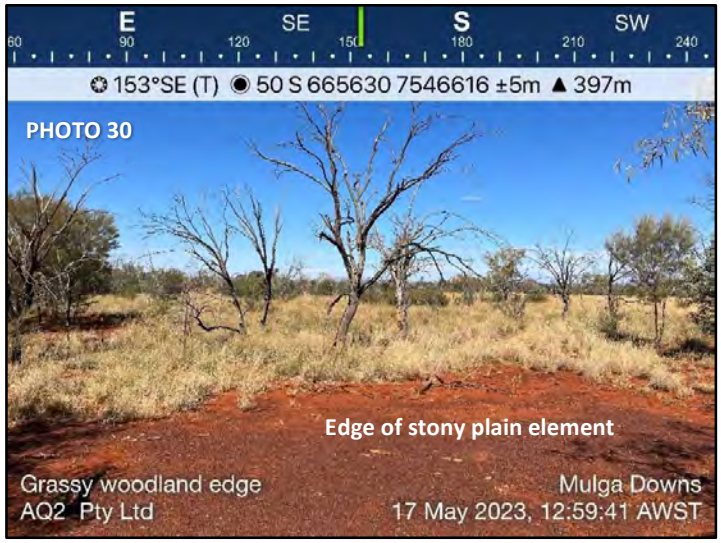

N
NE
E
56°NE (T) 50 S 664501 7546678 ±5m ▲ 403m
PHOTO 26
Sediment
settlement area
AQ2 Pty Ltd
Mulga Downs
19 May 2023,
09:27:41 AWST


NW N NE E SI
330 0 30 60 90 120
42°NE (T) 50 S 654535 7552168 ±5m 408m
PHOTO 27
Transition from stony plain
AQ2 Pty Ltd
Mulga Downs
18 May 2023, 09:59:32 AWST


NW N NE E
300 330 0 30 60 90 120
32°NE (T) 50 S 669032 7544992 ±5m 406m
PHOTO 28
Horseshoe drainage
AQ2 Pty Ltd
Mulga Downs
17 May 2023, 14:01:08 AWST

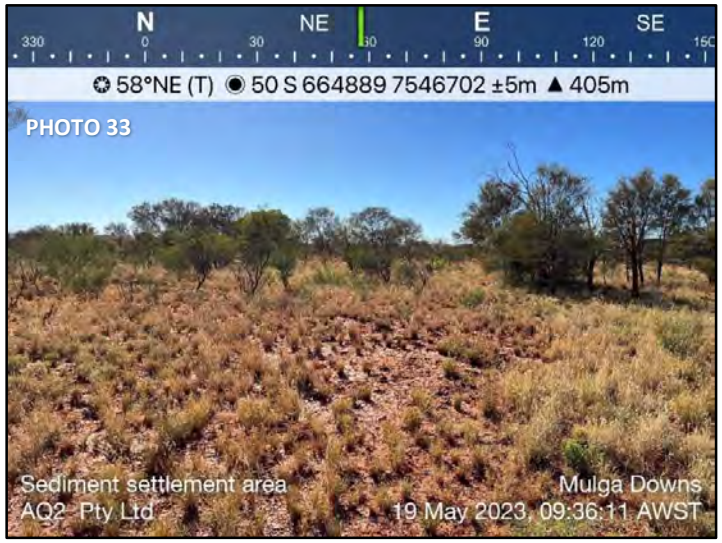
Example Photographs – Loamy Flats







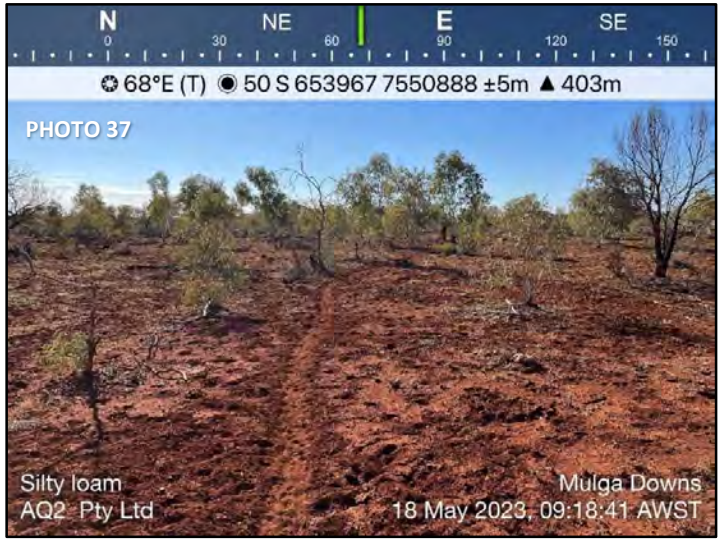



N NE E SE
330 0 30 60 90 120 150
58°NE (T) 50 S 664889 7546702 ±5m ▲ 405m
PHOTO 33
Sediment settlement area
AQ2 Pty Ltd
Mulga Downs
19 May 2023, 09:36:11 AWST


NW N NE
346°N (T) 50 S 664918 7546720 ±5m ▲ 398m
PHOTO 34
Sediment settlement area
AQ2 Pty Ltd
Mulga Downs
19 May 2023, 09:37:10 AWST

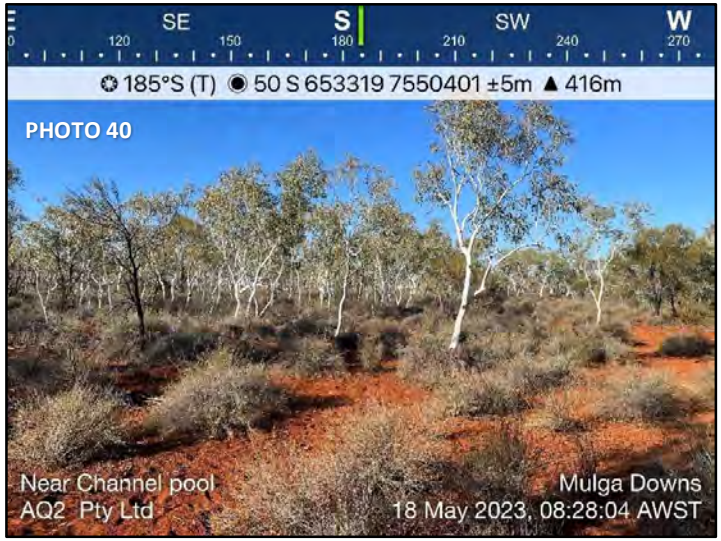

SW W NW N
210 240 270 300 330 0
287°W (T) 50 S 661431 7547790 ±4m ▲ 410m
PHOTO 35
Grassy clay flat
AQ2 Pty Ltd
Mulga Downs
19 May 2023, 07:21:06 AWST


SE S SW
150 180 210 240
192°S (T) 50 S 661427 7547790 ±4m ▲ 407m
PHOTO 36
Grassy clay flat
AQ2 Pty Ltd
Mulga Downs
19 May 2023, 07:22:34 AWST

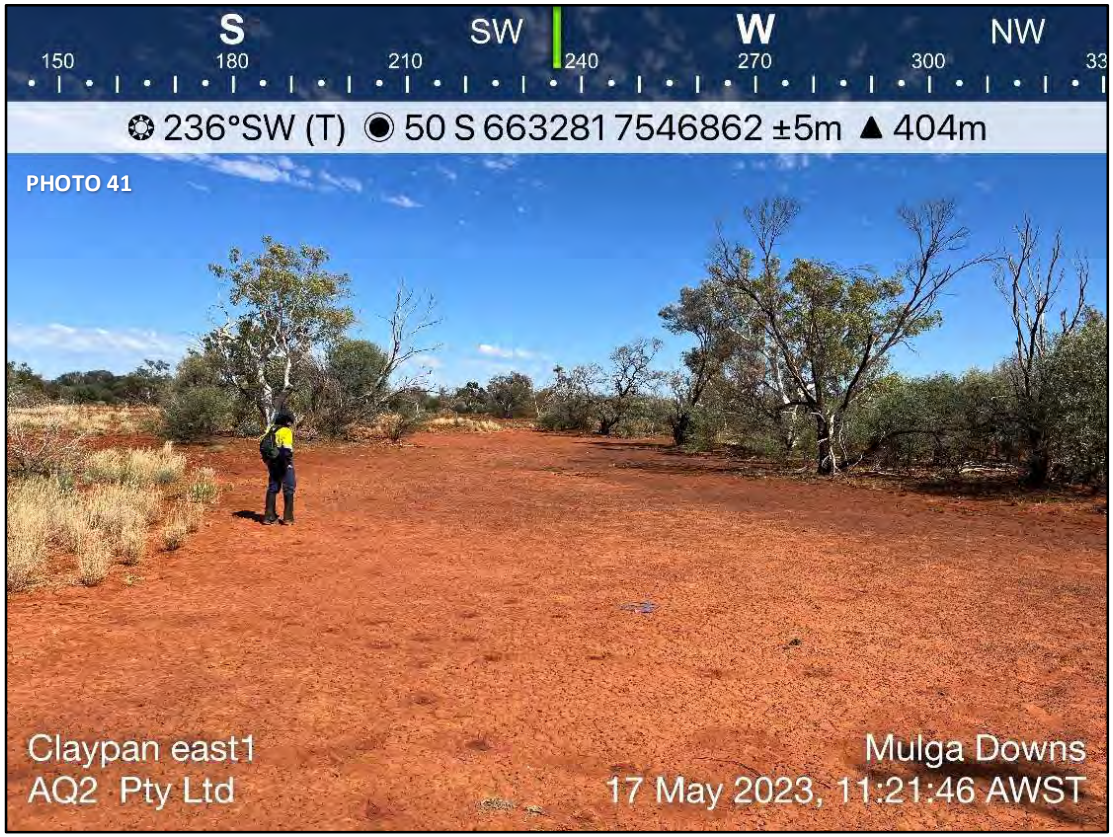

N NE E SE
0 30 60 90 120 150
68°E (T) 50 S 653967 7550888 ±5m 403m
PHOTO 37
Silty loam
AQ2 Pty Ltd
Mulga Downs
18 May 2023, 09:18:41 AWST


South Elevation
20°N (T) 50 S 643814 7553244 ±5m 405m
PHOTO 38
Intermittent channel (dissipates at either end) on the valley flats
Stony plain transition
AQ2 Pty Ltd
Mulga Downs
18 May 2023, 14:12:53 AWST

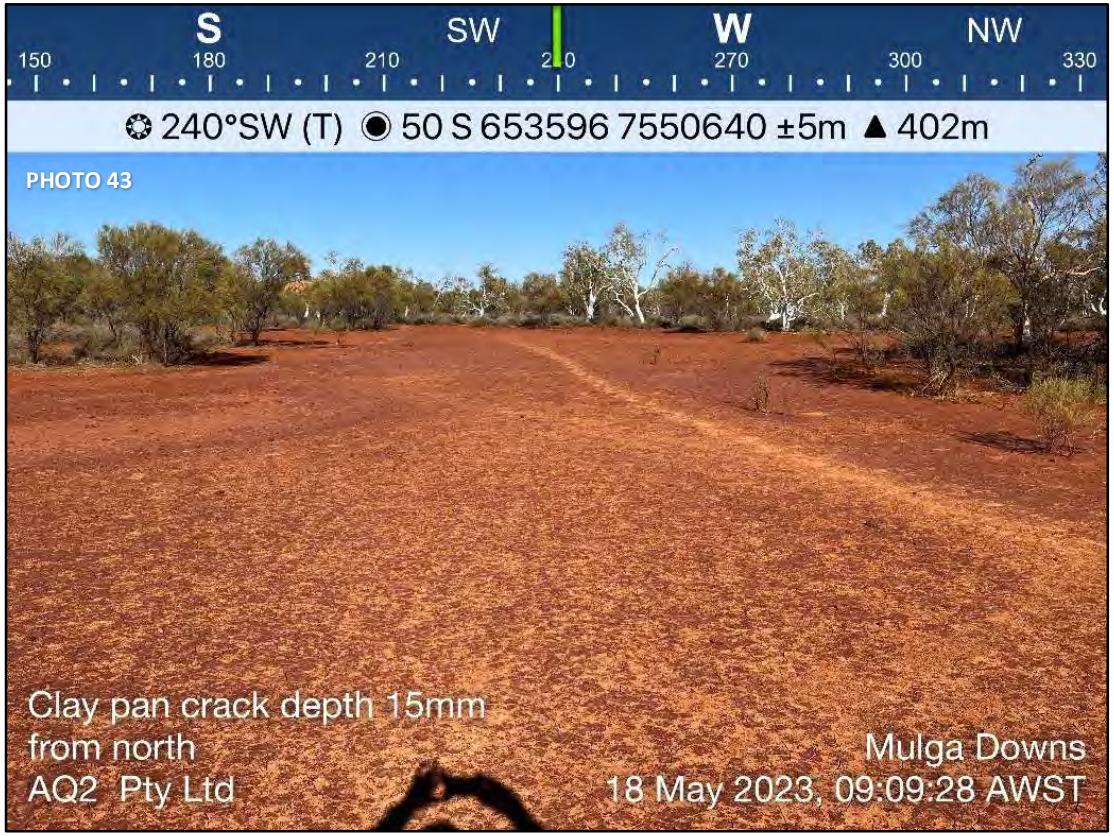

W NW N NE
270 300 330 0 30 60
355°N (T) 50 S 654633 7552048 ±5m 398m
PHOTO 39
Silty loam landscape
upslope moist
AQ2 Pty Ltd
Mulga Downs
18 May 2023, 09:52:26 AWST


SE S SW W
120 150 180 210 240 270
185°S (T) 50 S 653319 7550401 ±5m 416m
PHOTO 40
Near Channel pool
AQ2 Pty Ltd
Mulga Downs
18 May 2023, 08:28:04 AWST

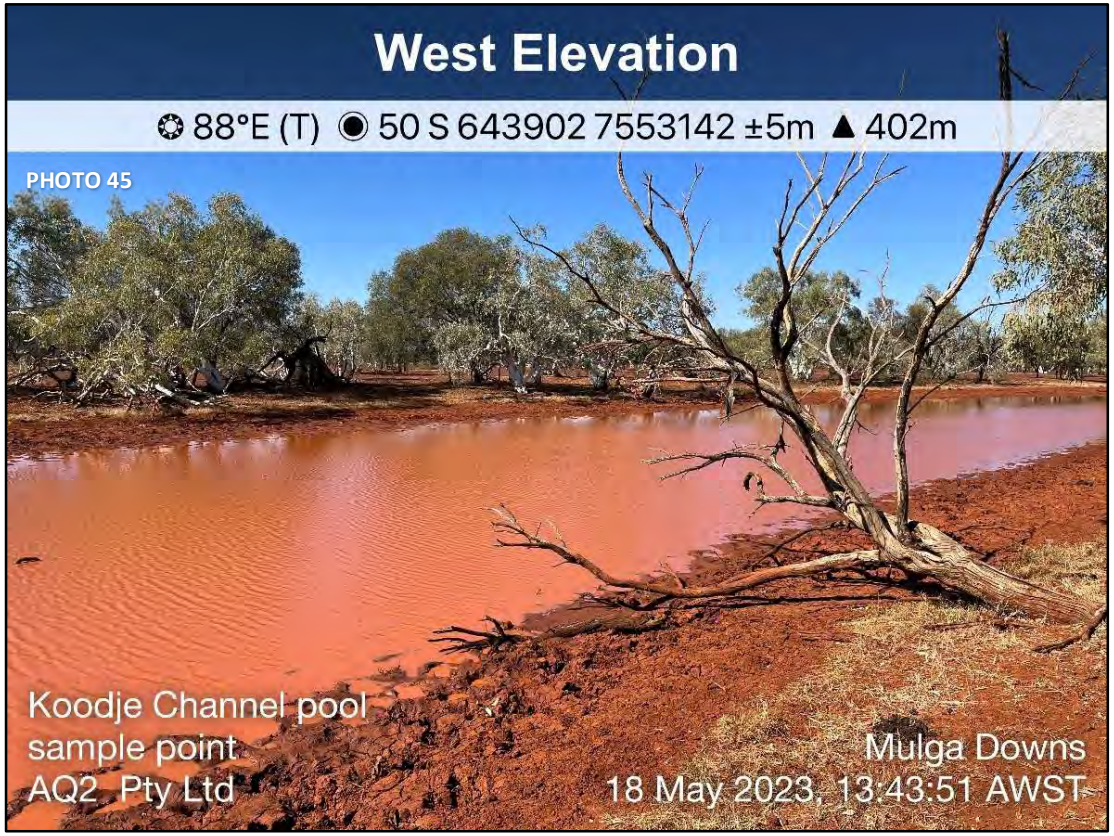
Example Photographs – Ponding Flats

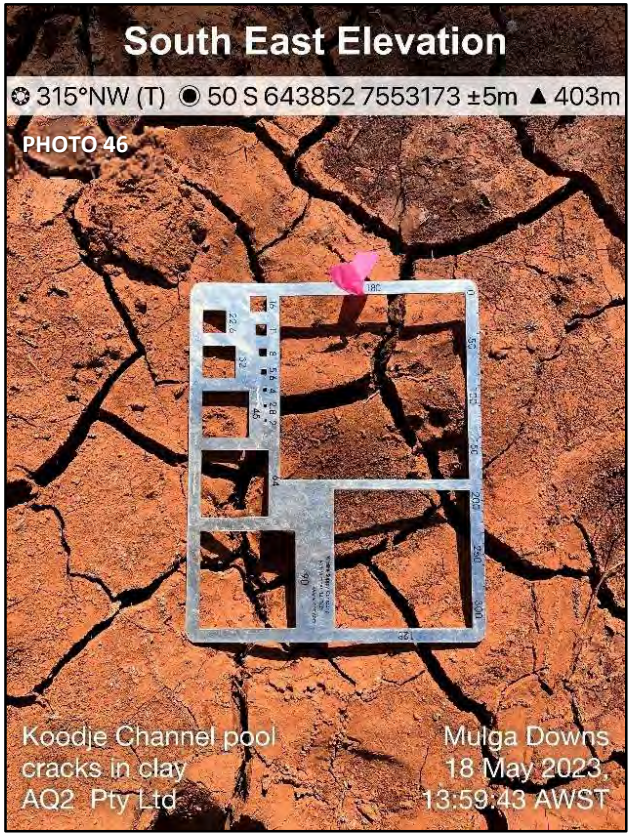


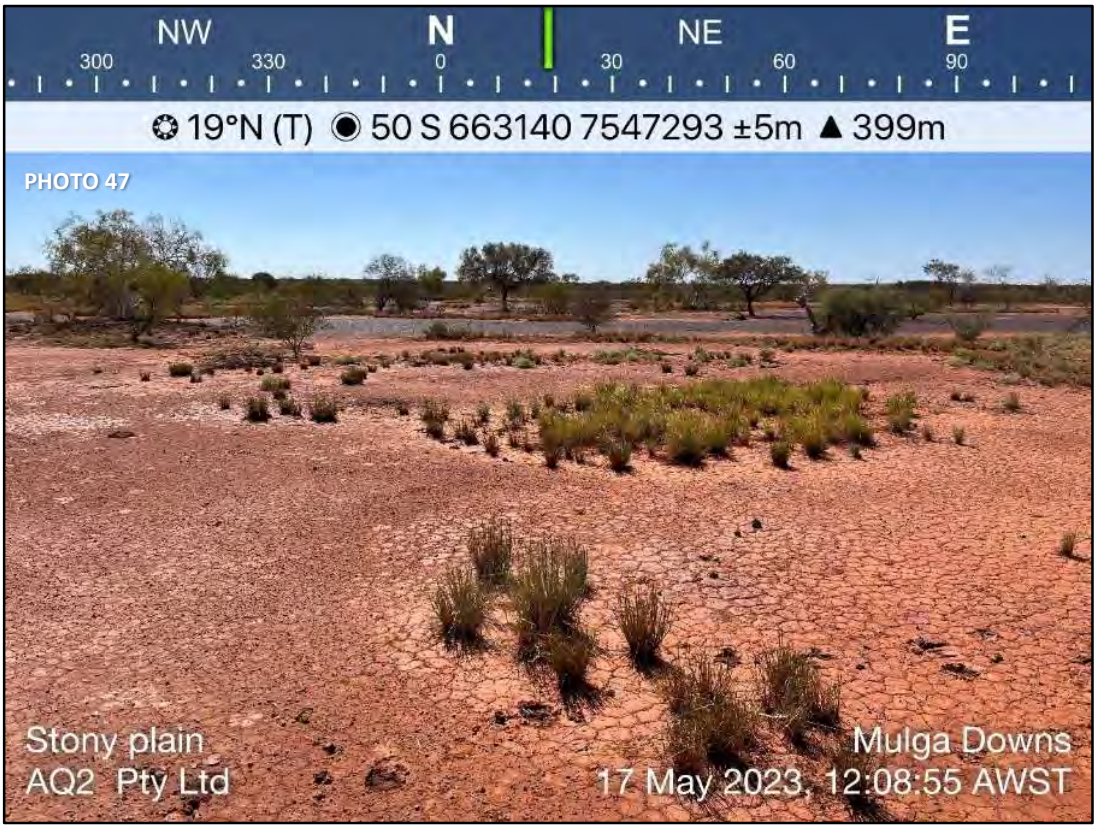


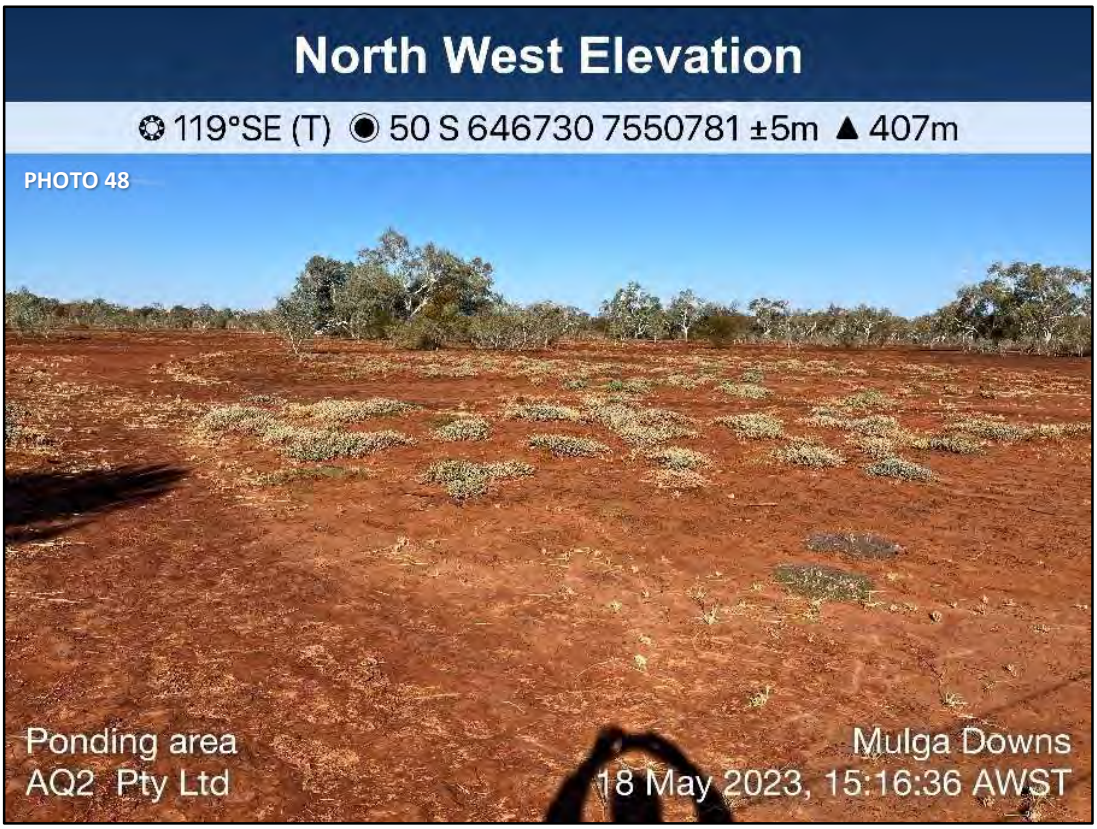

S
SW
W
NW
150
180
210
240
270
300
330
240°SW (T) 50 S 653596 7550640 ±5m 402m
PHOTO 43
Clay pan crack depth 15mm
from north
AQ2 Pty Ltd
Mulga Downs
18 May 2023, 09:09:28 AWST


E
SE
S
90
120
150
180
130°SE (T) 50 S 653551 7550608 ±5m 402m
PHOTO 44
Clay pan crack
depth 15mm
AQ2 Pty Ltd
Mulga Downs
18 May 2023,
09:03:42 AWST


West Elevation
88°E (T) 50 S 643902 7553142 ±5m 402m
PHOTO 45
Koodje Channel pool
sample point
AQ2 Pty Ltd
Mulga Downs
18 May 2023, 13:43:51 AWST


South East Elevation
315°NW (T) 50 S 643852 7553173 ±5m 403m
PHOTO 46
Koodje Channel pool
cracks in clay
AQ2 Pty Ltd
Mulga Downs
18 May 2023,
13:59:43 AWST


NW
N
NE
E
300
330
0
30
60
90
19°N (T) 50 S 663140 7547293 ±5m ▲ 399m
PHOTO 47
Stony plain
AQ2 Pty Ltd
Mulga Downs
17 May 2023, 12:08:55 AWST


North West Elevation
119°SE (T) 50 S 646730 7550781 ±5m ▲ 407m
PHOTO 48
Ponding area
AQ2 Pty Ltd
Mulga Downs
18 May 2023, 15:16:36 AWST

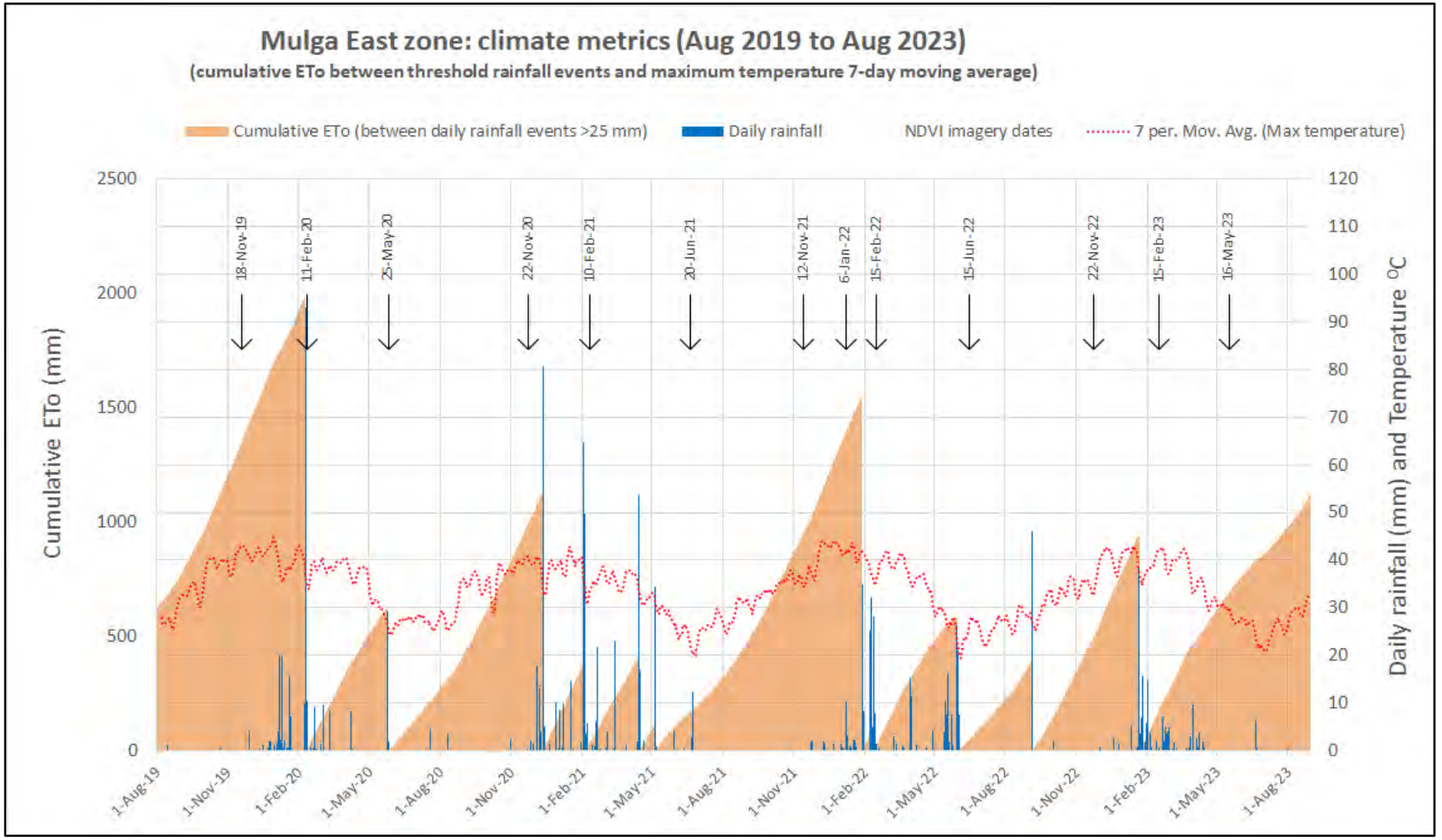
APPENDIX 0
REINTREPRETED SOIL SALINITY, NITRATE-N, PLANT-AVAILABLE S FOR LADNSCPE ECOHYDROGICAL UNITS

					Salinity Class				Plant Available Sulfur (mg/kg)				Nitrate-N (mg/kg)			
Sample ID	**Easting**	**Northing**	**Mine Earth land unit**	**AQ2 Ecohydrological unit**	**Depth 0-5 cm**	**Depth 10-20 cm**	**Depth 40-50 cm**	**Depth 90-100 cm**	**Depth 0-5 cm**	**Depth 10-20 cm**	**Depth 40-50 cm**	**Depth 90-100 cm**	**Depth 0-5 cm**	**Depth 10-20 cm**	**Depth 40-50 cm**	**Depth 90-100 cm**
ME02	651144	7549479	Calcareous flats	Calcrete Flats	non saline	slightly saline			58	69			7	14		
ME11	651397	7545489	Calcareous flats	Calcrete Flats	non saline	moderately saline	slightly saline	slightly saline	6	75	54	51	3	5	4	5
ME22	656005	7543001	Calcareous flats	Calcrete Flats	moderately saline	slightly saline	slightly saline	non saline	192	58	47	8	20	8	4	6
ME05	656695	7548183	Calcareous flats	Calcrete Flats	non saline	non saline	non saline	very saline	3	3	2	593	2	4	2	1
AQ2_H	661446	7546809	n/a	Calcrete Flats	non saline				8							
AQ2_C	663004	7546386	n/a	Calcrete Flats	non saline				6							
ME19	647198	7551591	Alluvial plain	Loamy Flats	non saline	non saline	non saline	moderately saline	2	2	6	120	5	4	1	1
AQ2_F	653289	7550364	n/a	Loamy Flats	non saline				5							
AQ2_E	654013	7550891	n/a	Loamy Flats	non saline				9							
ME18	651304	7550408	Clay pan	Ponding Flats	extremely saline	extremely saline	extremely saline	extremely saline	534	1,731	1,744	1,473	28	48	19	3
AQ2_D	653551	7550608	n/a	Ponding Flats	very saline				251							
AQ2_B	663272	7546859	n/a	Ponding Flats	non saline				11							

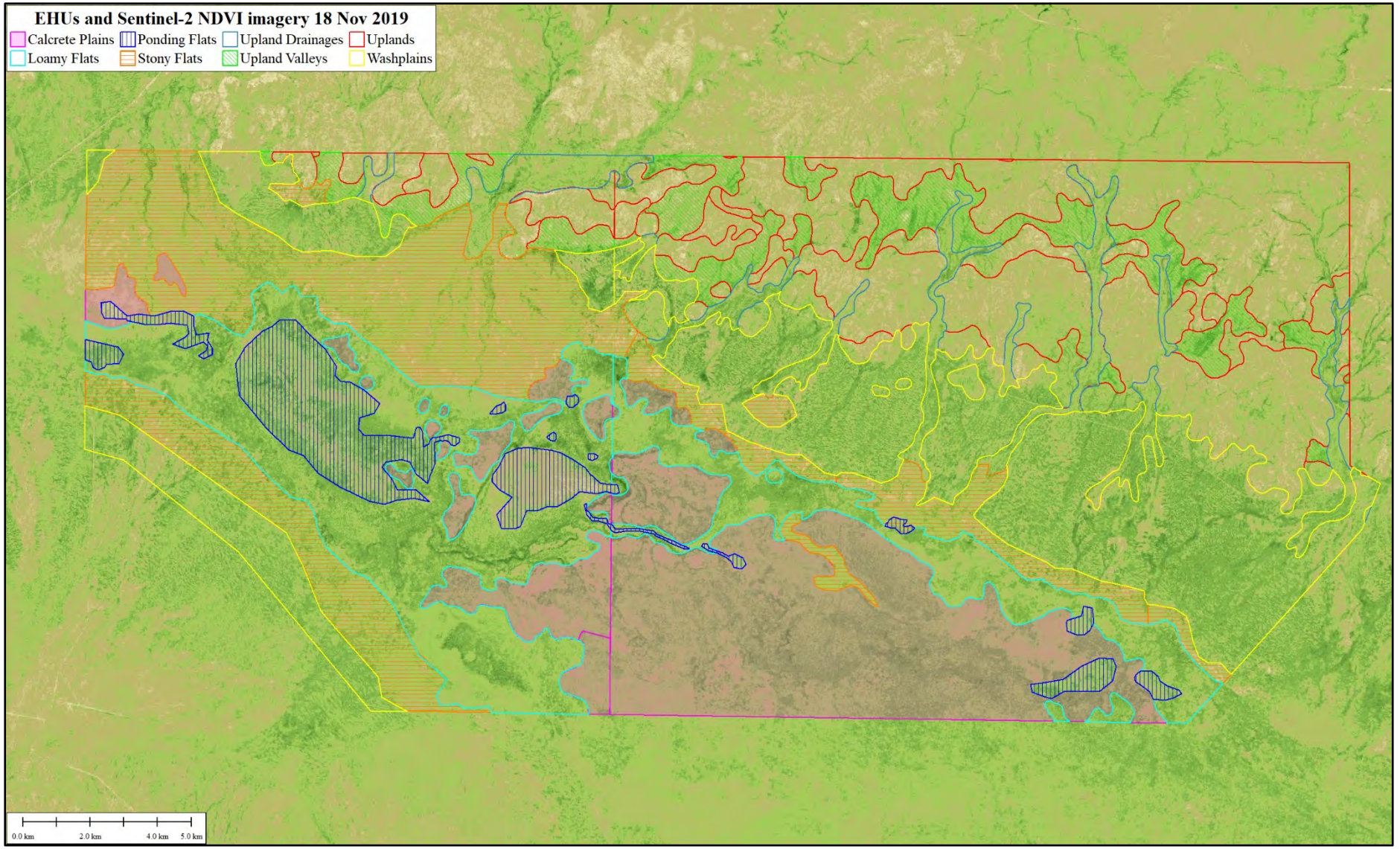
					Salinity Class				Plant Available Sulfur (mg/kg)				Nitrate-N (mg/kg)			
Sample ID	**Easting**	**Northing**	**Mine Earth land unit**	**AQ2 Ecohydrological unit**	**Depth 0-5 cm**	**Depth 10-20 cm**	**Depth 40-50 cm**	**Depth 90-100 cm**	**Depth 0-5 cm**	**Depth 10-20 cm**	**Depth 40-50 cm**	**Depth 90-100 cm**	**Depth 0-5 cm**	**Depth 10-20 cm**	**Depth 40-50 cm**	**Depth 90-100 cm**
ME15	642859	7553566	Alluvial plain	Stony Flats	moderately saline	very saline			6	48			12	37		
AQ2_G	643902	7553142	n/a	Stony Flats	non saline				8							
ME21	644808	7548262	Floodplain	Stony Flats	non saline	non saline	slightly saline	moderately saline	3	2	9	154	3	5	16	3
ME07	649918	7552382	Alluvial plain	Stony Flats	non saline	extremely saline	extremely saline	extremely saline	8	110	2,260	530	3	25	60	48
ME14	650285	7554538	Alluvial plain	Stony Flats	non saline	non saline	moderately saline	very saline	6	7	30	862	3	6	30	40
ME16	651489	7551206	Clay pan	Stony Flats	extremely saline	extremely saline			82	157			50	91		
ME17	652219	7552541	Floodplain	Stony Flats	slightly saline	very saline	extremely saline	extremely saline	32	29	173	1,411	5	73	155	24
ME10	655657	7551787	Alluvial plain	Stony Flats	moderately saline	very saline	extremely saline	extremely saline	236	921	1,737	5,041	6	12	20	18
ME08	663200	7547988	Floodplain	Stony Flats	extremely saline	extremely saline	extremely saline	extremely saline	273	534	261	1,662	23	47	23	7
ME06	665839	7547904	Alluvial plain	Stony Flats	non saline	non saline	slightly saline	very saline	1	5	18	62	1	8	35	18
AQ2_A	651087	7555304	n/a	Upland Drainages	non saline				3							
ME13	655131	7555635	Low hills / Rises	Uplands	non saline	non saline			3	5			3	3		

					Salinity Class				Plant Available Sulfur (mg/kg)				Nitrate-N (mg/kg)			
Sample ID	**Easting**	**Northing**	**Mine Earth land unit**	**AQ2 Ecohydrological unit**	**Depth 0-5 cm**	**Depth 10-20 cm**	**Depth 40-50 cm**	**Depth 90-100 cm**	**Depth 0-5 cm**	**Depth 10-20 cm**	**Depth 40-50 cm**	**Depth 90-100 cm**	**Depth 0-5 cm**	**Depth 10-20 cm**	**Depth 40-50 cm**	**Depth 90-100 cm**
ME12	655742	7552867	Low hills / Rises	Uplands	non saline	non saline			2	7			2	2		
ME01	657091	7555423	Low hills / Rises	Uplands	non saline	non saline			3	5			2	2		
ME09	661075	7554694	Low hills / Rises	Uplands	non saline	non saline			3	4			2	1		
ME03	667419	7552187	Low hills / Rises	Uplands	non saline	non saline			2	3			2	2		
ME20	671324	7550523	Low hills / Rises	Uplands	non saline	non saline			8	6			7	3		
ME24	659652	7552314	Alluvial plain	Alluvial Fan Washplains	non saline				2				2			
ME23	663609	7551651	Alluvial plain	Alluvial Fan Washplains	non saline				3				9			
ME04	669994	7547876	Alluvial plain	Alluvial Fan Washplains	non saline	non saline	non saline	non saline	7	3	4	3	20	19	6	2

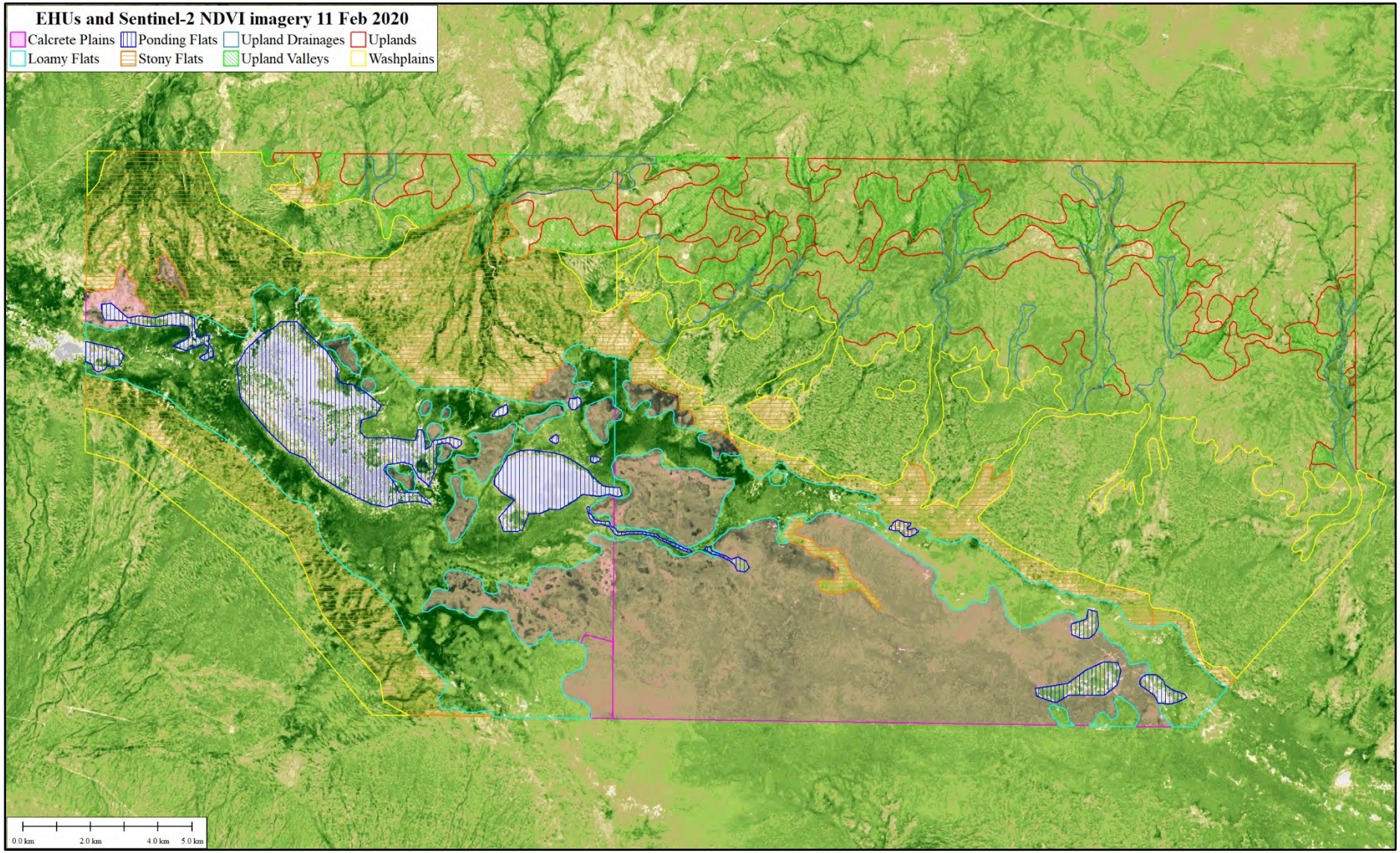
APPENDIX P
SENTINEL-2 IMAGERY



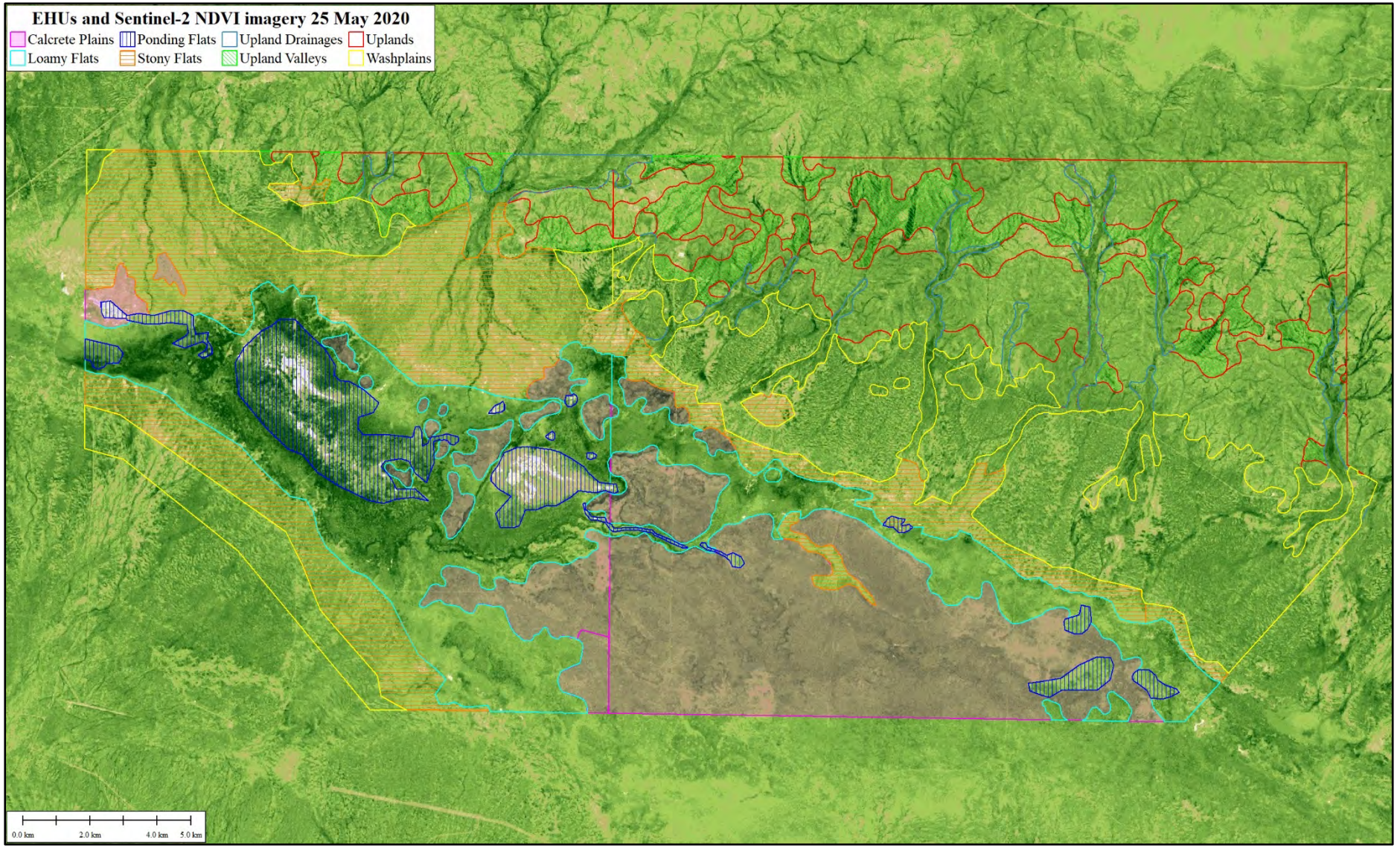
Climate data sourced from SILO Data Drill (Lat, Long: -22.10 118.50 DECIMAL DEGREES)



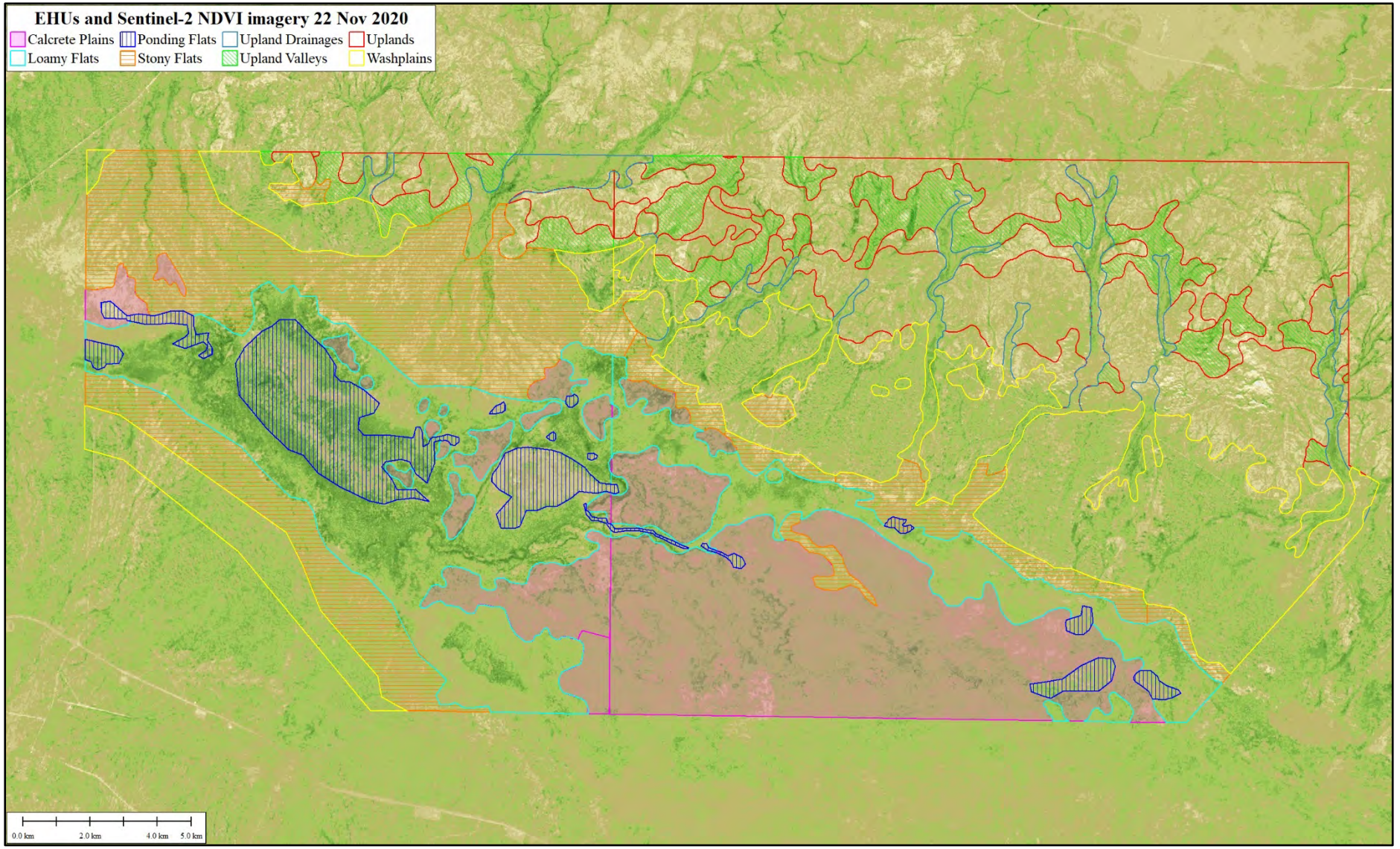
After protracted drought



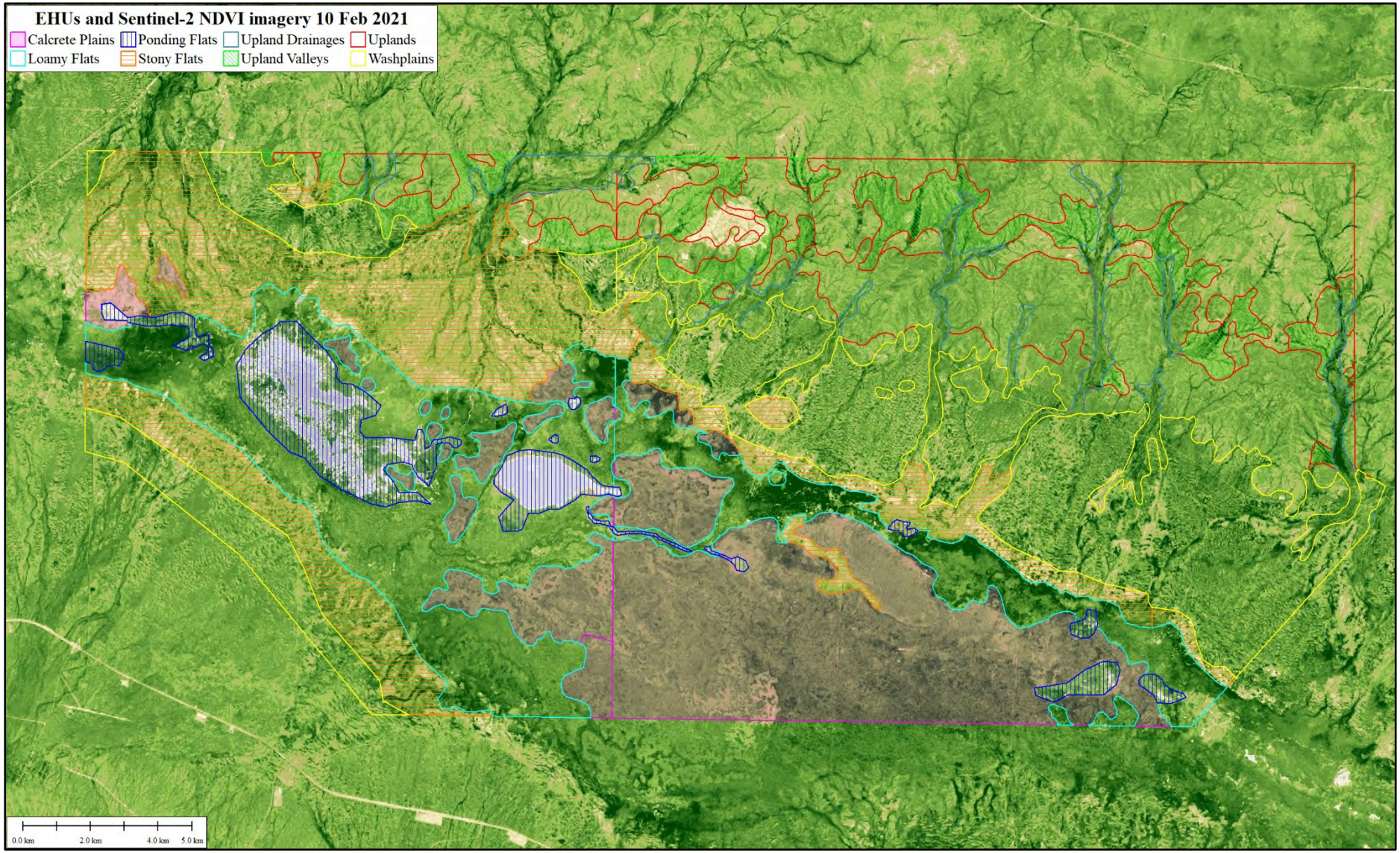
Shortly after major rainfall event (approx. 90 mm)



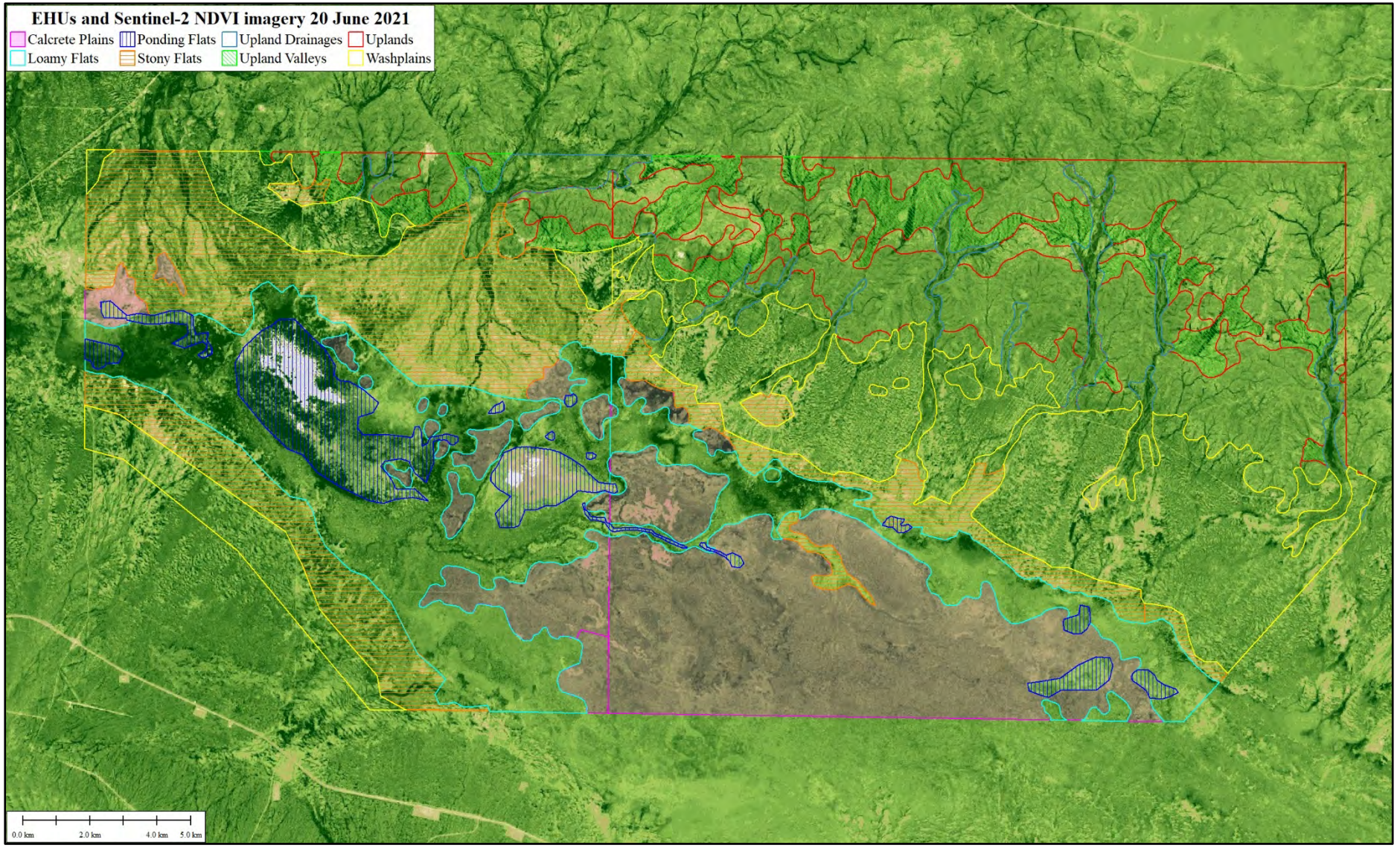
Shortly after rainfall event (approx. 30 mm)



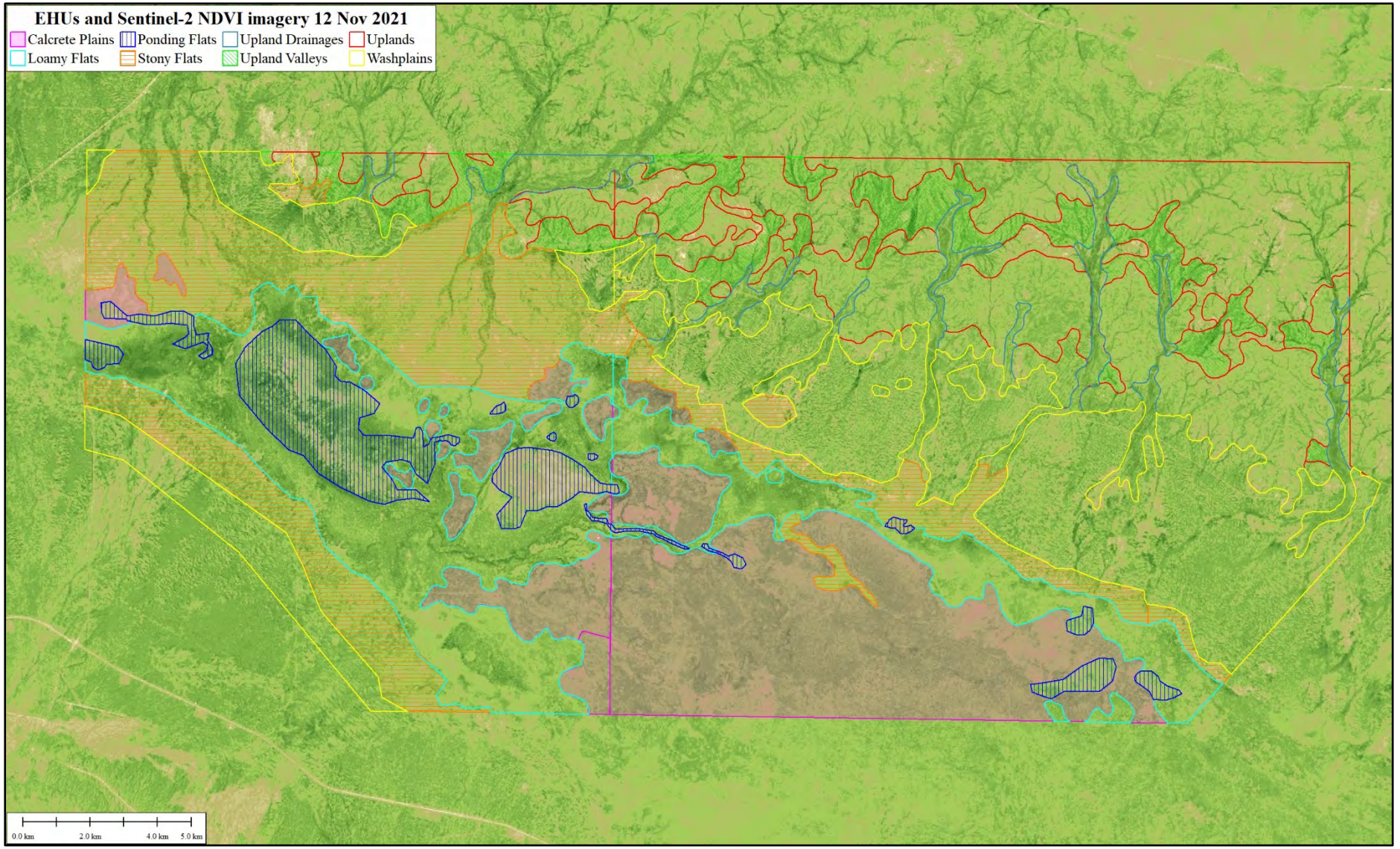
After protracted drought



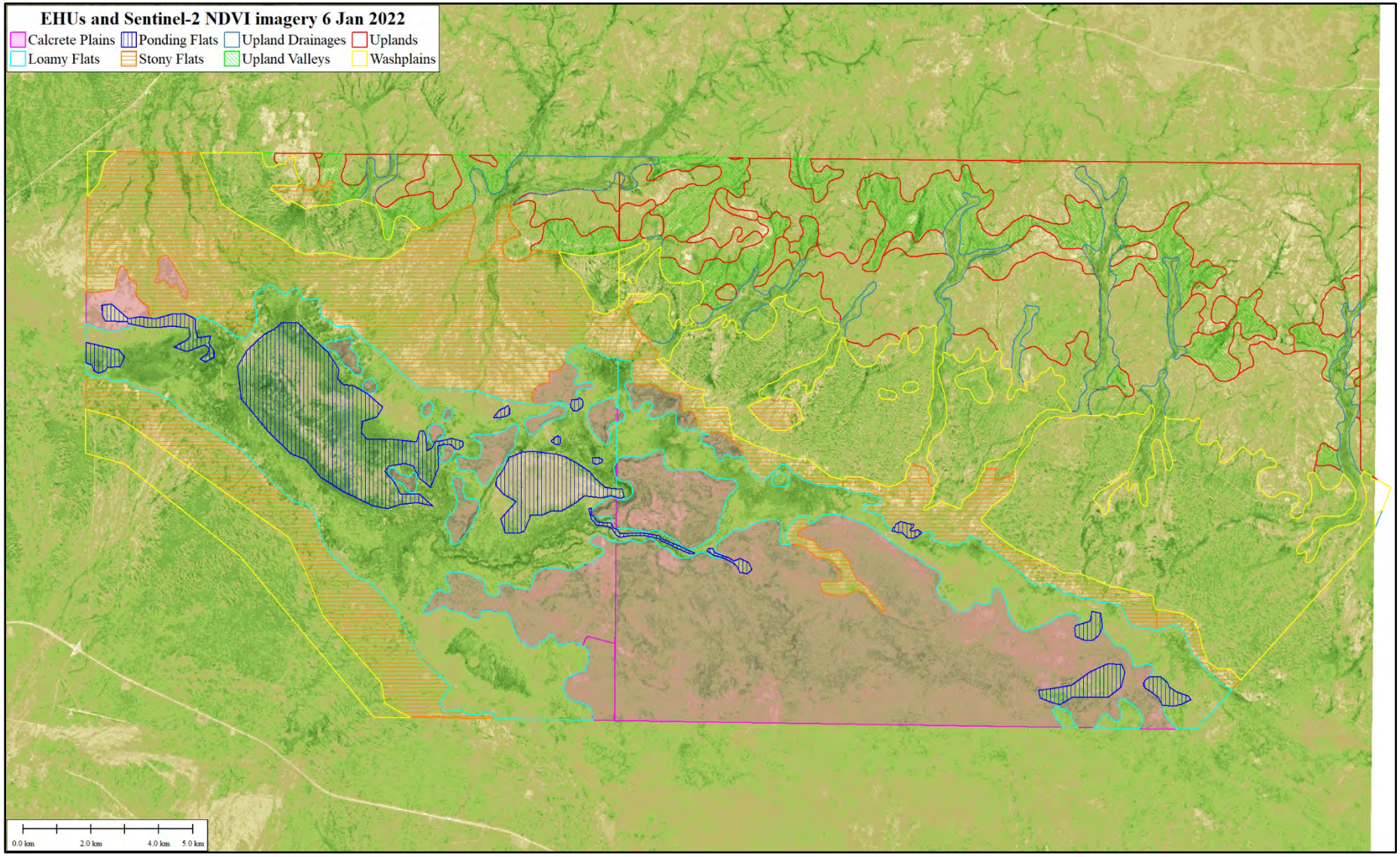
After significant seasonal rains



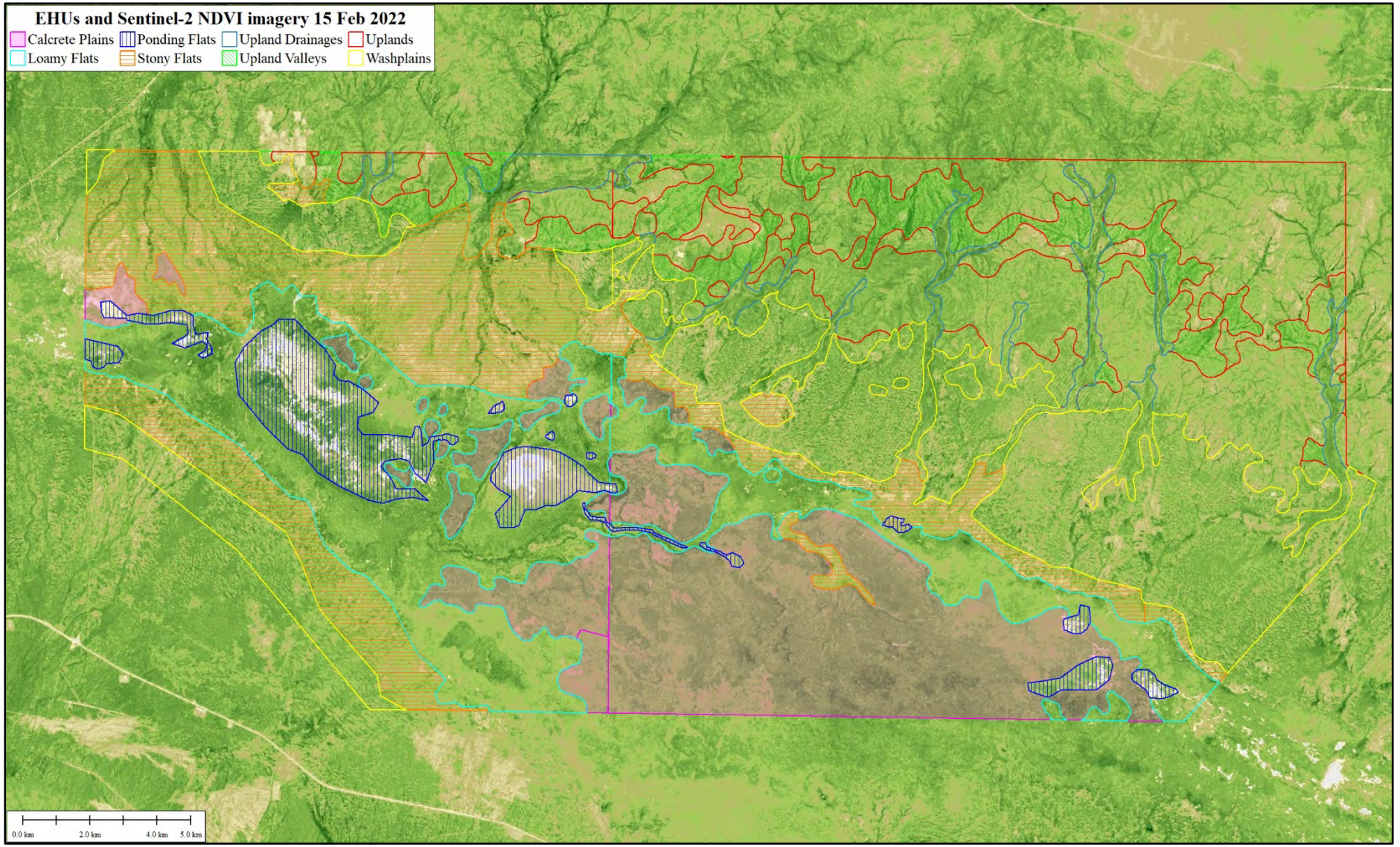
End of a wet period



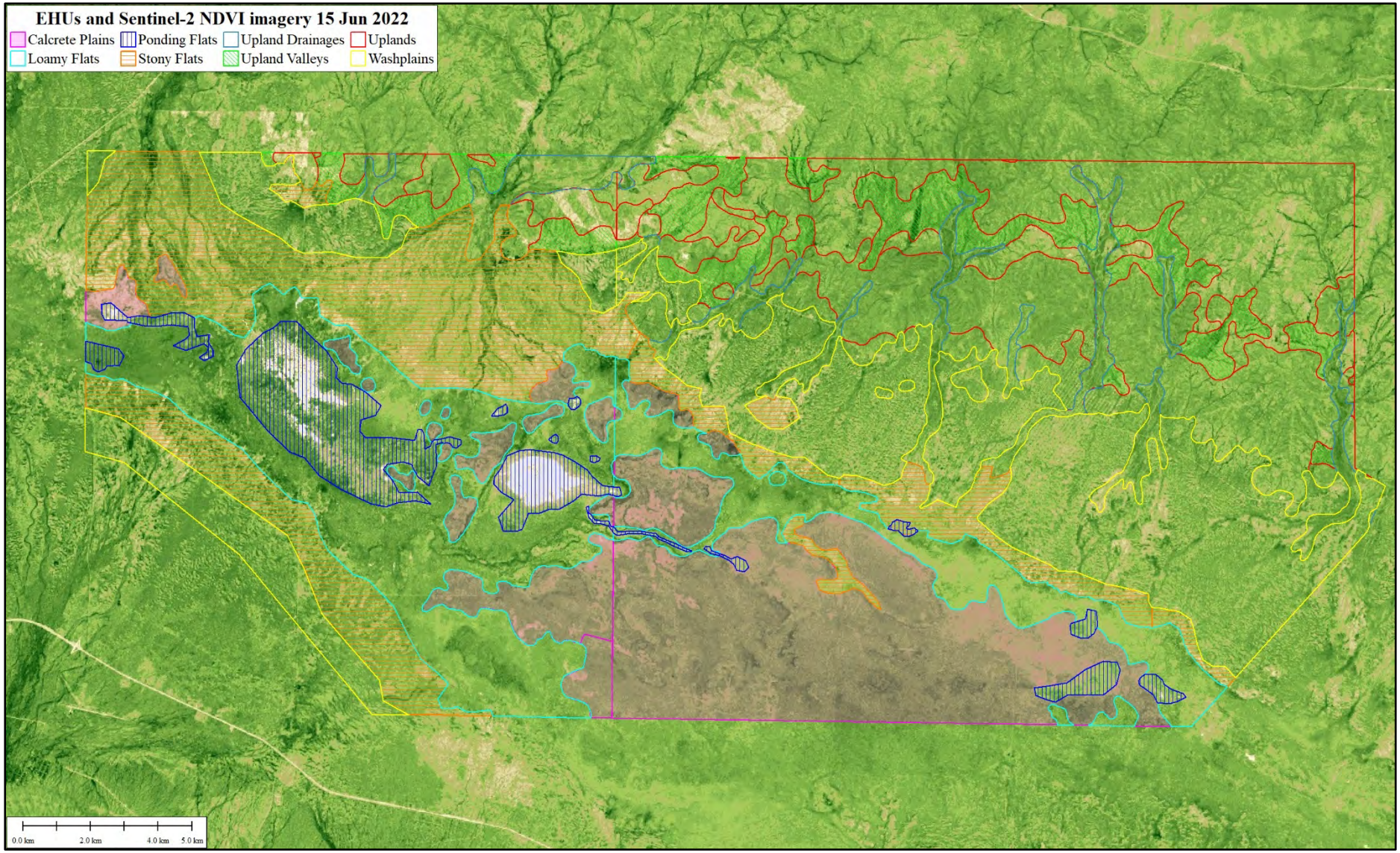
After protracted drought



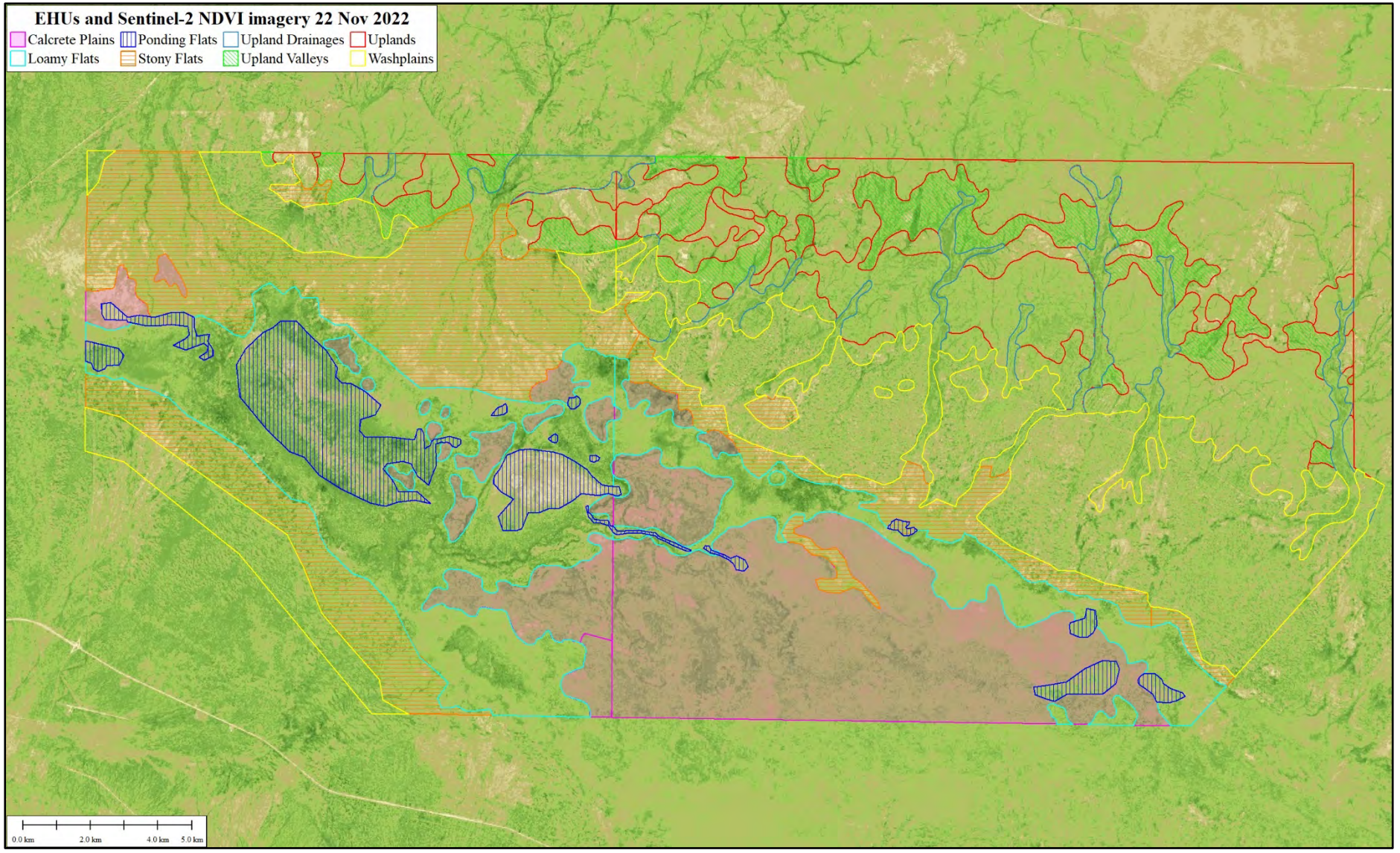
After protracted drought persisting into ‘wet’ season



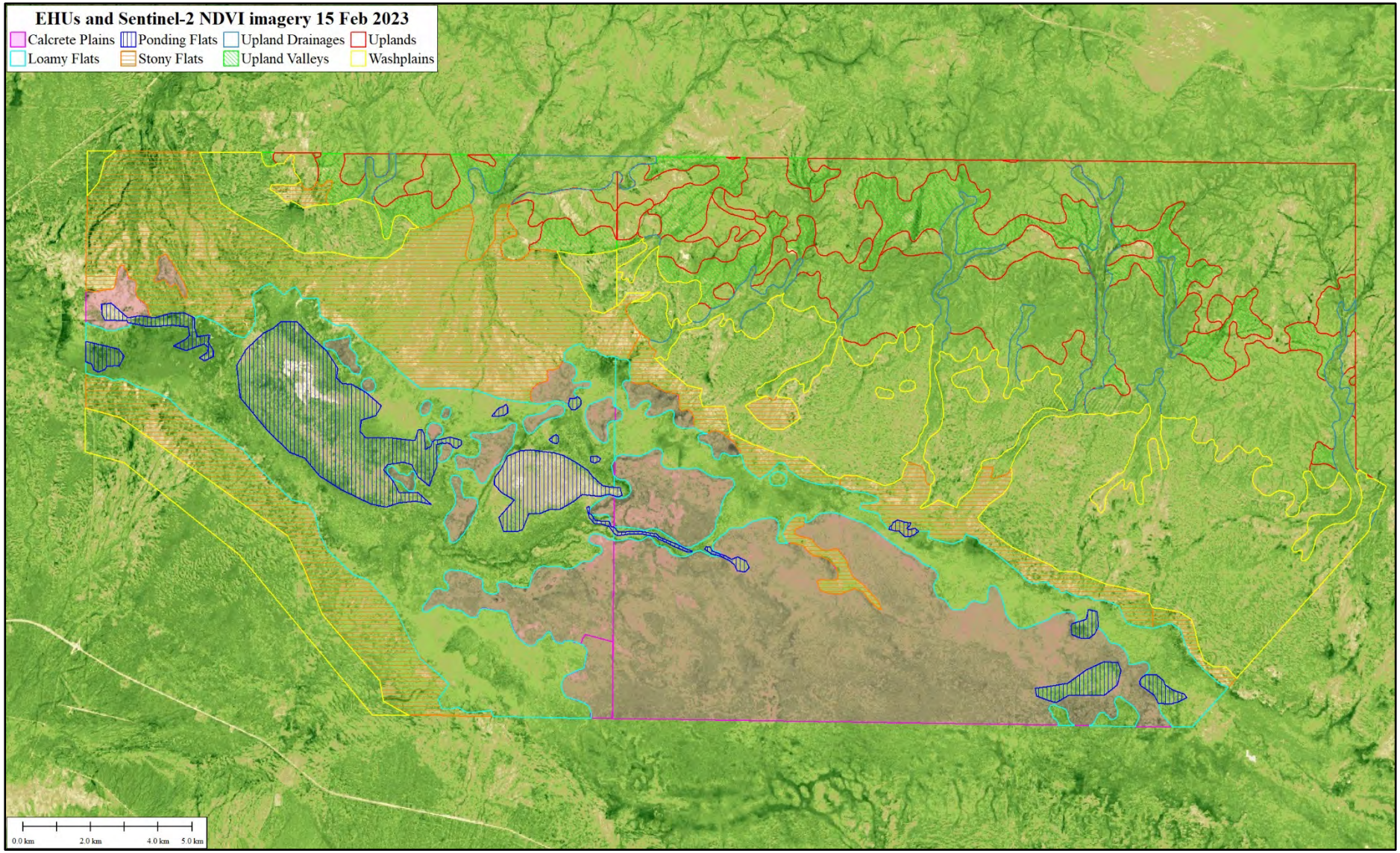
After significant seasonal rains



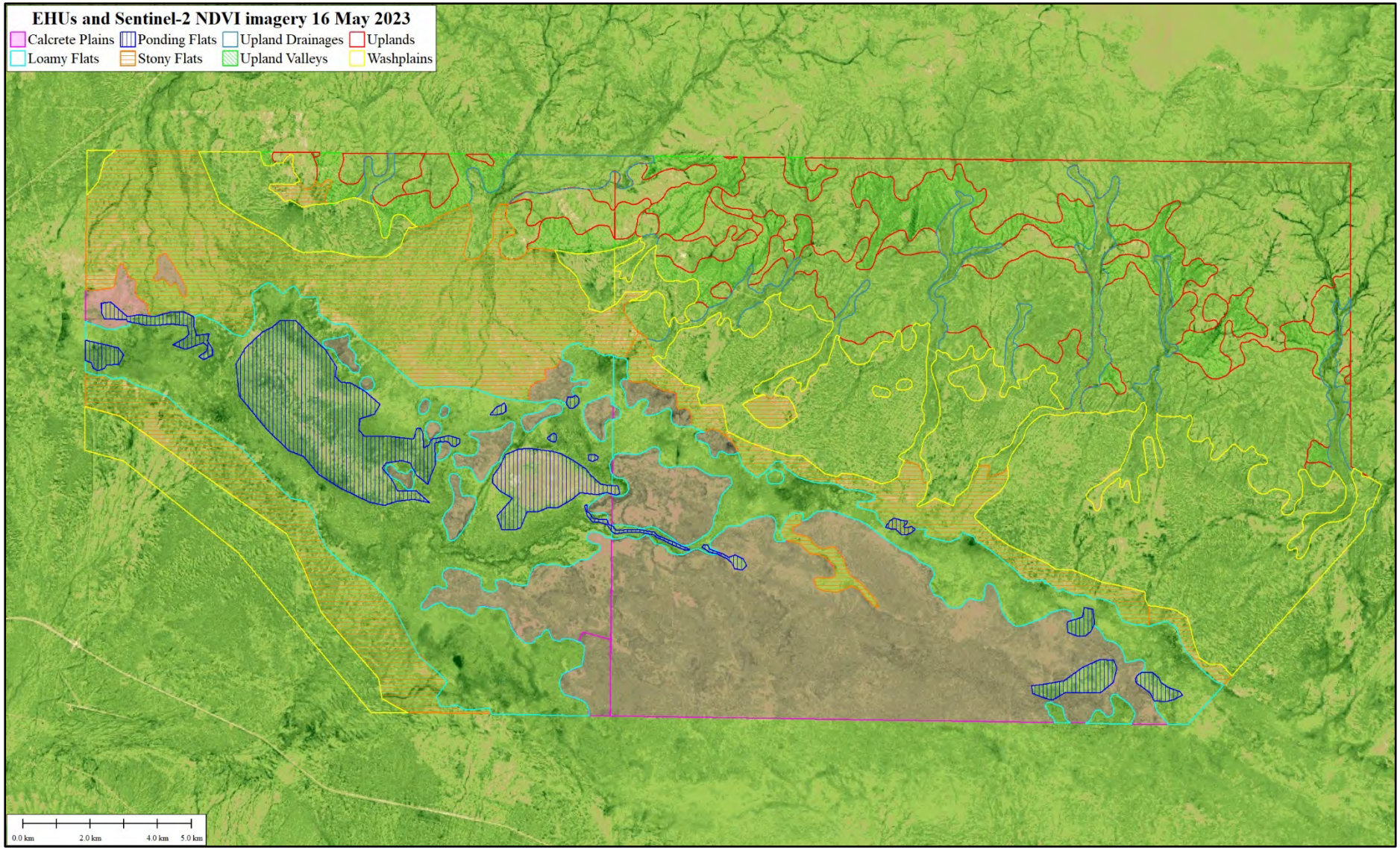
End of a wet period



Drying phase after a large (approx. 50 mm) rainfall event in September 2022



After a wet period



Beginning of a drying phase

APPENDIX Q
MULGA DOWNS GROUNDWATER DEPENDENT VEGETATION REMOTE SENSING ASSESSMENT (WOODGIS 2021)

MULGA DOWNS
GROUNDWATER DEPENDENT VEGETATION REMOTE SENSING ASSESSMENT



DRAFT A

17 August 2021

PREPARED FOR

AQ2

PREPARED BY

Woodgis
ENVIRONMENTAL ASSESSMENT & MANAGEMENT

Woodgis
ENVIRONMENTAL ASSESSMENT & MANAGEMENT

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- The data supplied may not be supplied to other organisations, nor be used for any purpose other than for the project for which they have been provided, without the prior written consent of the Executive Director, Department of Biodiversity, Conservation and Attractions; and
- Specific locality information for threatened flora is regarded as confidential, and should be treated as such by receiving organisations. Specific locality information for threatened flora may not be used in public reports without the written permission of the Executive Director, Department of Biodiversity, Conservation and Attractions.

RECOMMENDED REFERENCE:

Woodgis (2021) *Mulga Downs Groundwater Dependent Vegetation Remote Sensing Assessment*, unpublished report by Woodgis Environmental Assessment and Management for AQ2.

COVER PHOTOGRAPH:

Eucalyptus victrix drainageline in Area of Interest
Source: Duncan Storey, Director / Consulting Hydrogeologist, AQ2 Pty Ltd

ACRONYMS AND ABBREVIATIONS

The following acronyms are used in this report for succinctness:

AOI	Area of Interest
DBCA	(WA) Department of Biodiversity, Conservation and Attractions
GDE	Groundwater Dependent Ecosystem
GDV	Groundwater Dependent Vegetation
GEM	Groundwater-dependent Ecosystem Mapping
km	kilometres
m	metres
NDMI	Normalised Difference Moisture Index
NDVI	Normalised Difference Vegetation Index
NDWI	Normalised Difference Wetness Index
NVIS	National Vegetation Information System
WA	Western Australia/n

EXECUTIVE SUMMARY

A desktop assessment to identify areas of potential Groundwater Dependent Vegetation was undertaken to supplement hydrological studies by AQ2 in the vicinity of Mulga Downs in the Pilbara region.

The 290,960 hectare Area of Interest (AOI) in the Fortescue Valley at the western end of the Fortescue Marsh was located approximately 70 km north-east of Tom Price, 115 km west-south-west of Nullagine; and 120 km north-west of Newman.

Data from 211 vegetation quadrats in the AOI were consolidated into a single classification of six broad vegetation groups. All six broad vegetation groups can be broadly considered relatively 'fast drying' and non-groundwater dependent. *Eucalyptus victrix,* a facultative phreatophyte that can utilise but does not require access to groundwater, was recorded over significant portions of the AOI but *Melaleuca argentea* and *Eucalyptus camaldulensis,* trees that are associated with greater groundwater availability, were not recorded in quadrats.

All quadrats exhibited drying after rain as declines in the analysed multispectral indices, Normalised Difference Vegetation Index and Normalised Difference Wetness Index. Two quadrats exhibited drying at a slower rate than all other sites.

A single quadrat in the AOI was explicitly identified as groundwater-fed in the source documents. Site FV48 has been observed as having gradually flowing water without connection other surface water and has been described as a groundwater-fed permanent marginally subsaline river pool with three stygofaunal species. Floristic data in the absence of these observations would not lead to the identification of this site as groundwater dependent due to absence of phreatophytic tree species. Multispectral analysis indicated drying of this 'permanent' river pool, but high NDVI and NDWI values persisted in nearby areas which leads to the interpretation that whilst the pool may contract it is not necessarily impermanent or that groundwater becomes disconnected from the surface during dry seasons.

A quadrat with unusually dense/vigorous vegetation was identified in the multispectral analysis but field observations are likely required to explain whether this is associated with groundwater availability or other factors such as localized surface water impedance. Quadrat M-MWQ28 was classified as a *Acacia distans* and *Eucalyptus victrix* woodland*,* but more detailed floristic or site data was not available.

Areas that could be further investigated for potential Groundwater Dependent Vegetation (GDV) were identified on the basis of them exceeding multispectral index thresholds for non-groundwater dependent vegetation in the AOI. These areas cover 29 hectares, 0.01% of the AOI, with the more extensive large areas along Hooley Creek and the Fortescue River in the northwest of the AOI.

Further refinement of the multispectral analysis can be undertaken but additional field observations in potential GDV areas should be obtained to direct this.

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1. INTRODUCTION

1.1. Background and Objectives

AQ2 engaged Woodgis to undertake a desktop assessment to identify areas of potential Groundwater Dependent Vegetation (GDV) in a portion of the Fortescue Valley in the vicinity of Mulga Downs, to supplement hydrological studies.

1.2. Location in the Pilbara region

The Area of Interest (AOI) is located in the Pilbara region of Western Australia. Figure 1 shows the AOI at the western end of the Fortescue Marshes, approximately:

- 70 km north-east of Tom Price;
- 115 km west-south-west of Nullagine; and
- 120 km north-west of Newman.

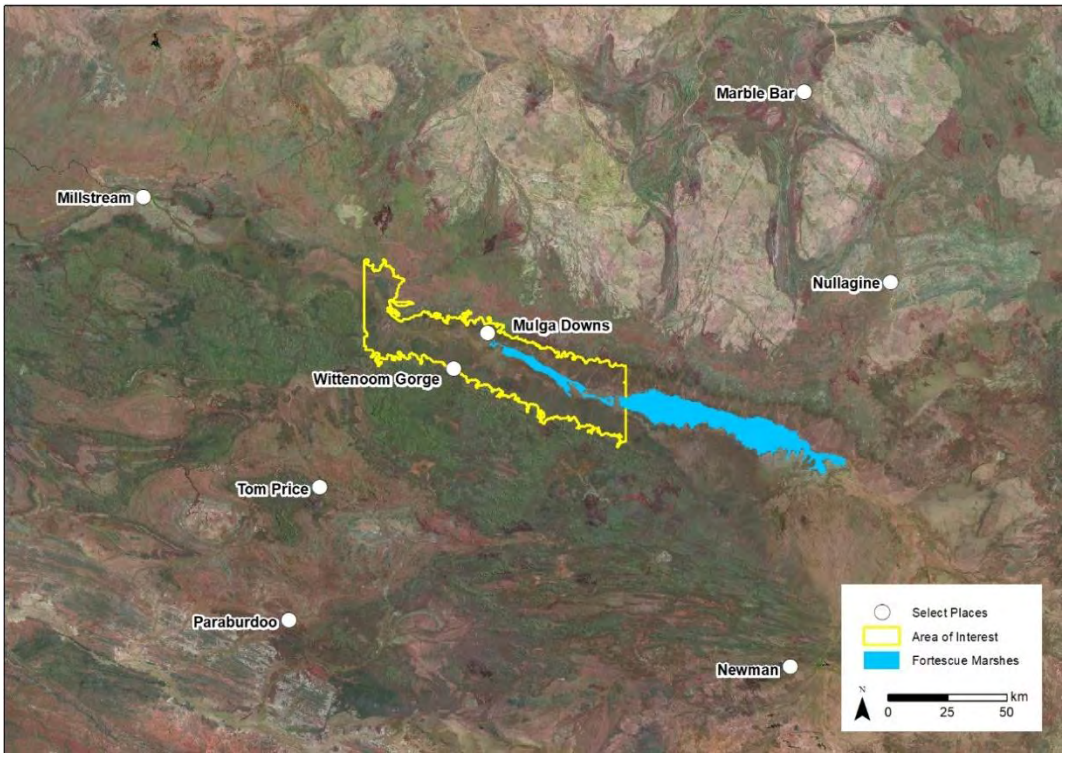


Figure 1: Location of AOI

1.3. Area of Interest (AOI)

The AOI covers approximately 290,960 hectares, with the boundary defined:

- to the east and west by the limits of the Sentinel 2 satellite image tile T50KPA; and
- to the north and south by the boundaries of land systems, which are areas with recurring patterns of landforms, soils and vegetation at a scale 1:250,000 that exist within hierarchy of soil-landscape mapping units for the rangelands and arid Interior of Western Australia (Tille, 2006).

The land systems in the AOI are described in Table 1 and shown in Figure 2.

The extents of the land type groupings of the land systems are listed in Table 2, and shown in Figure 3.

Table 1: Descriptions for Land Systems within AOI

Land System	Description
Adrian	Stony plains and low silcrete hills supporting hard spinifex grasslands.
Boolgeeda	Stony lower slopes and plains below hill systems supporting hard and soft spinifex grasslands or mulga shrublands.
Brockman	Gilgai alluvial plains with cracking clay soils supporting tussock grasslands.
Calcrete	Low calcrete platforms and plains supporting shrubby hard spinifex grasslands.
Christmas	Stony alluvial plains supporting snakewood and mulga shrublands with sparse tussock grasses.
Coolibah	Flood plains with weakly gilgaied clay soils supporting coolibah woodlands with tussock grass understorey.
Cowra	Plains fringing the Marsh land system and supporting snakewood and mulga shrublands with some halophytic undershrubs.
Fan	Washplains and gilgai plains supporting groved mulga shrublands and minor tussock grasslands.
Hooley	Alluvial clay plains supporting a mosaic of snakewood shrublands and tussock grasslands.
Jamindie	Stony hardpan plains and rises supporting groved mulga shrublands, occasionally with spinifex understorey.
Jurrawarrina	Hardpan plains and alluvial tracts supporting mulga shrublands with tussock and spinifex grasses.
Lake Bed	Bare lake beds inundated for short periods after rain.
Marsh	Lakebeds and flood plains subject to regular inundation, supporting samphire shrublands, salt water couch grasslands and halophytic shrublands.
McKay	Hills, ridges, plateaux remnants and breakaways of meta sedimentary and sedimentary rocks supporting hard spinifex grasslands.
Newman	Rugged jaspilite plateaux, ridges and mountains supporting hard spinifex grasslands.
Platform	Dissected slopes and raised plains supporting hard spinifex grasslands.
River	Active flood plains, major rivers and banks supporting grassy eucalypt woodlands, tussock grasslands and soft spinifex grasslands.
Urandy	Stony plains, alluvial plains and drainage lines supporting shrubby soft spinifex grasslands.
Total	

Source: Van Vreeswyk, Payne, Leighton, & Hennig (2004)

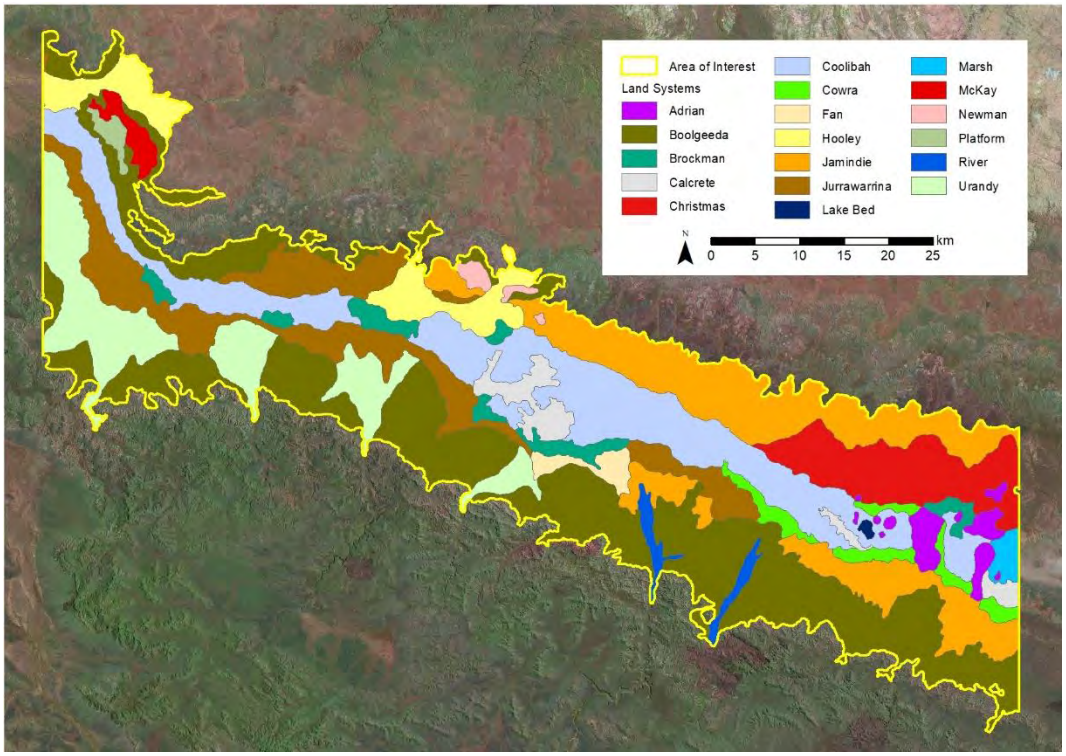


Figure 2: Land Systems within AOI

Source: Van Vreeswyk, Payne, Leighton, & Hennig (2004)

Table 2: Extents of Land Types and Land Systems within AOI

Land Type Land System	Extent in AOI (ha)
Hills and ranges with spinifex grasslands	**3,817**
McKay Land System	2,419
Newman Land System	1,398
Stony plains with spinifex grasslands	**82,364**
Boolgeeda Land System	81,080
Platform Land System	1,284
Stony plains with acacia shrublands and halophytic shrublands	**4,701**
Adrian Land System	4,701
Wash plains on hardpan with mulga shrublands	**75,834**
Fan Land System	2,504
Jamindie Land System	42,676
Jurrawarrina Land System	30,654
Calcrete plains with spinifex grasslands	**6,287**
Calcrete Land System	6,287
Alluvial and sandy plains with soft spinifex grasslands	**26,132**
Urandy Land System	26,132
Alluvial plains with acacia shrublands	**35,614**
Christmas Land System	17,235
Cowra Land System	5,357
Hooley Land System	13,022
Alluvial plains with tussock grasslands	**7,096**
Brockman Land System	7,096
River plains with grassy woodlands and tussock grasslands	**47,181**
Coolibah Land System	44,416
River Land System	2,766
Salt lakes and fringing alluvial plains with halophytic shrublands	**1,677**
Marsh Land System	1,677
Lake Bed	**256**
Lake Bed Land System	256
Total	**290,958**

Source: Van Vreeswyk, Payne, Leighton, & Hennig (2004)

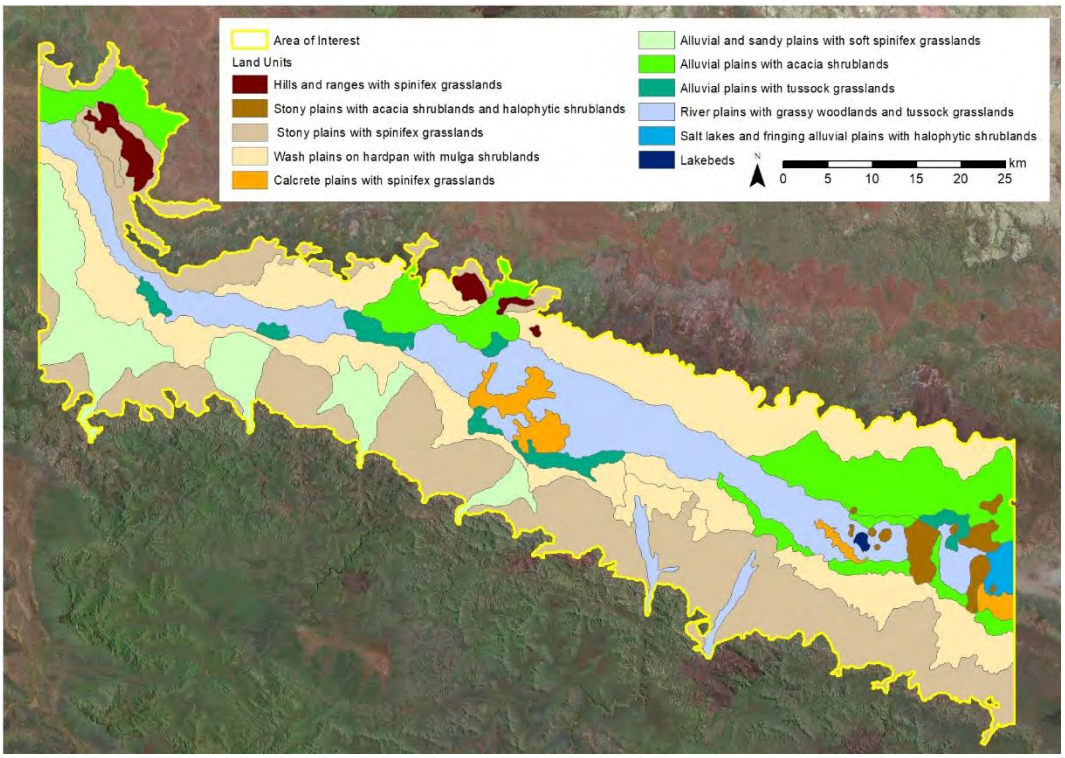


Figure 3: Land Types in AOI

Source: Van Vreeswyk, Payne, Leighton, & Hennig (2004)

2. METHODS

2.1. Groundwater-dependent Ecosystem Mapping

A Groundwater-dependent Ecosystem Mapping (GEM) method was proposed by Barron *et al.* (2012) based on interpretation of the land surface response to the drying process, identifying areas that maintain constant amount of green vegetation (greenness) and high level of surface moisture (wetness) are likely to have access to groundwater.

This GEM method can be used to map the following five land cover classes that can be used for delineation of potential GDV:

1. **Permanent waterbodies** – areas where surface water persists after a prolonged dry period.
2. **'Not drying' potential obligate phreatophytic vegetation** – areas where vegetation with permanent access to water are likely to sustain a consistently high greenness and wetness as measured, even after a prolonged dry period,
3. **'Slow drying' potential facultative phreatophytic vegetation** - areas where vegetation access to water is diminishing are likely to show some level of greenness and wetness reduction after a prolonged dry period; and
4. **'Fast drying' non-groundwater dependent vegetation** – areas where the root zone is often disconnected to groundwater, greenness and wetness measured at the surface can be dramatically reduced at the end of a prolonged drying period; and
5. **'Dry' non-groundwater dependent vegetation** - areas that exhibit invariant but low greenness that are not expected to be associated with groundwater-dependent ecosystems.

The GEM defines land cover classes, as per Table 3, utilising two multispectral indices:

- **Normalised Difference Vegetation Index (NDVI)** – a ratio based on near-infrared and red wavelengths that is a reliable indicator of chlorophyll levels (density and vigour of vegetation). NDVI values vary between -1 and +1, typically ranging between 0.1 and 0.7 for vegetation in Australia (Bureau of Meteorology, 2020). Higher values are associated with greater density and greenness of the plant canopy and values decrease as plants become water stressed, diseased or die (Bureau of Meteorology, 2020). NDVI values <0 are indicative of waterbodies (Bureau of Meteorology, 2020); and
- **Normalised Difference Moisture Index (NDWI)** – a ratio based on near-infrared wavelengths and shortwave infrared wavelengths was used by Barron *et al.* (2012). This version of Normalised Difference Wetness Index (NDWI) is equivalent to Normalised Difference Moisture Index **(**NDMI), and the indices NDWI and NDMI are often referred to interchangeably (Sinergise, 2021)). Barron *et al.* (2012) used NDWI to measure the moisture content of vegetation. Values vary between -1 and +1, with values <-0.8 associated with bare soil, values <-0.6 associated with very sparse vegetation, and plant water stress decreasing with increasing values >0 (Agricolus, 2021).

Average NDVI and NDWI values for vegetation site type groups are presented. Whilst average values are influenced by extreme values within datasets, median values can fluctuate stochastically within small datasets. Average and median NDVI values were compared for the AOI and whilst both supported consistent conclusions, average values produced more readily interpretable trends with less fluctuation.

Table 3: Land Cover Class Definition

Land Cover Classes	NDVI	NDWI
1 Permanent waterbodies	Low unchanging values	High unchanging values
2 'Not drying' potential obligate phreatophytic vegetation	High unchanging values	High unchanging values
3 'Slow drying' potential facultative phreatophytic vegetation	Small decrease in values over dry season	Small decrease in values over dry season
4 'Fast drying' non-groundwater dependent vegetation	Large decrease in values over dry season	Large decrease in values over dry season
5 'Dry' non-groundwater dependent sparse vegetation	Low unchanging values	Low unchanging values

The GEM method was applied to the AOI using:

- NDVI and NDWI values generated from Sentinel 2 satellite data (Section 3); and
- NDVI and NDWI thresholds calibrated with reference to existing vegetation data (Section 4).

2.2. Multispectral Data

Multispectral indices were generated using:

- cloud-free imagery captured by the European Space Agency's Copernicus Sentinel-2 satellites in 2017;
- red and near-infrared wavelengths (bands 4 and 8), both of 10 m x 10 m resolution for NDVI;
- near-infrared and short wave infrared 1 wavelengths (bands 8 and 11), of 10 m x 10 m and 20 m x 20 m resolution respectively for NDWI.

The analysis used maximum NDVI and NDWI values within 50 metres of quadrat co-ordinates:

- this reduced potentially confounding influence of low values associated with bare ground and surface water; and
- the typical size of vegetation quadrats in the Pilbara is 2,500 m^2 and co-ordinates may be located on the edge of vegetation types, especially where drainage features are small and/or narrow.

The dates of satellite imagery used are listed in Table 4 and shown in Figure 4, with the analysis characterised in terms of time since rain using:

- rainfall data from Bureau of Meteorology Weather Station 5026 at Wittenoom, which is located within the AOI; and
- the rain classes for the Pilbara presented by Beard (1975), with a rainfall event being a period of one or more consecutive days on which rain was recorded, and:
  - major effective rain being >20 mm;
  - minor effective rain being 6-20 mm; and
  - ineffective rain being < 6 mm (insufficient to promote plant growth).

Table 4: Intervals Between Rainfall Events and Satellite Imagery

Date of Sentinel Image	Days since Major Effective Rainfall Event (21.4 mm on 17-19 April 2017)	Days since Minor Effective Rainfall Event (7.4 mm on 8 November, 10.2 mm on 8 December)
17 May	28	
06 June	48	
16 July	88	
05 August	108	
14 September	148	
19 October	183	
28 November	223	20
18 December	243	10

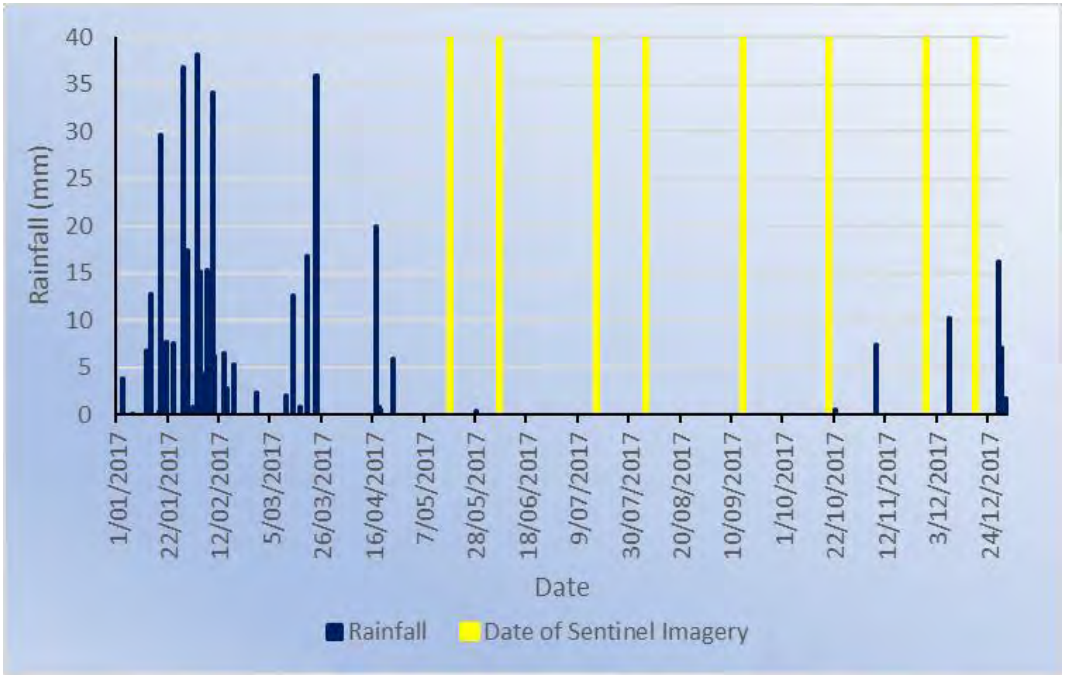


Figure 4: Satellite Imagery Capture in Relation to Time Since Rain

2.3. Vegetation Data

Vegetation datasets within the AOI were compiled:

- Fine resolution vegetation mapping was not available for the entirety of AOI; and
- Mapping of phreatophytic vegetation was required at a higher resolution 'than typical quadrat/relevé dominated sampling methodology and subsequent vegetation mapping undertaken in typical flora and vegetation surveys within WA', to support the impact assessment of the Greater Paraburdoo Iron Ore Hub Proposal (Naaykens, 2020).

Vegetation descriptions were obtained for 211 quadrats in the AOI from:

- Pilbara Biological Survey – Plants (DBCA, 2021), which included data from *The riparian flora and plant communities of the Pilbara region of Western Australia* (Lyons, 2015);
- *Strategen - JBS&G: Mulga East Iron Ore Project, Mine Study Area Detailed Flora and Vegetation Assessment 2019-2020* (Maia Environmental Consultancy, 2021);
- *Floristic Survey and Mapping of the Riparian and Halophyte Dominated Communities on the Fortescue Marsh (Martuyitha), Western Australia* (Markey, 2017);
- *Wetland Biodiversity Patterning Along the Middle to Upper Fortescue Valley (Pilbara Region: Western Australia) to Inform Conservation Planning* (Pinder, et al., 2017); and
- *Technical Bulletin No. 92 - An inventory and condition survey of the Pilbara region, Western Australia* (Van Vreeswyk, Payne, Leighton, & Hennig, 2004).

To fully integrate the datasets into a single overarching vegetation classification hierarchy, vegetation types were categorised according to site type and site type groups of Van Vreeswyk *et al* (2004), who in the Pilbara defined:

- 44 site types (which are equivalent to vegetation subformations under the NVIS, National Vegetation Information System, framework) defined in terms of combinations of dominant perennial plant species, and vegetation structure in conjunction with land surface (landforms and soils); and
- 11 site type groups defined in terms of broad vegetation structure and landforms.

The contribution of datasets to the analysis are indicated in Table 5.

Table 5: Number of Quadrats in Analysis by Source and Site Type Group

Source / Site Type Group	Pilbara Biological Survey (DBCA, 2021)	Mulga East (Maia Environmental Consultancy, 2021)	Fortescue Marsh (Markey, 2017)	Fortescue Valley Wetlands (Pinder, et al., 2017)	Inventory and Condition Survey (Van Vreeswyk, Payne, Leighton, & Hennig, 2004)	Total
A: Hill hummock grassland		1			1	2
D: Plain hummock grassland		26	1		4	31
F: Sheet flood hardpan plain sclerophyll shrubland	3	47			4	54
I: Alluvial plain tussock grassland	4	29		11	8	52
J: Alluvial plain halophytic shrubland	1	16	2	3	1	23
K: Drainage shrubland and woodland	2	31	1	13	2	49
Total	10	150	4	27	20	211

The distribution of quadrats across the AOI is shown in Figure 5.

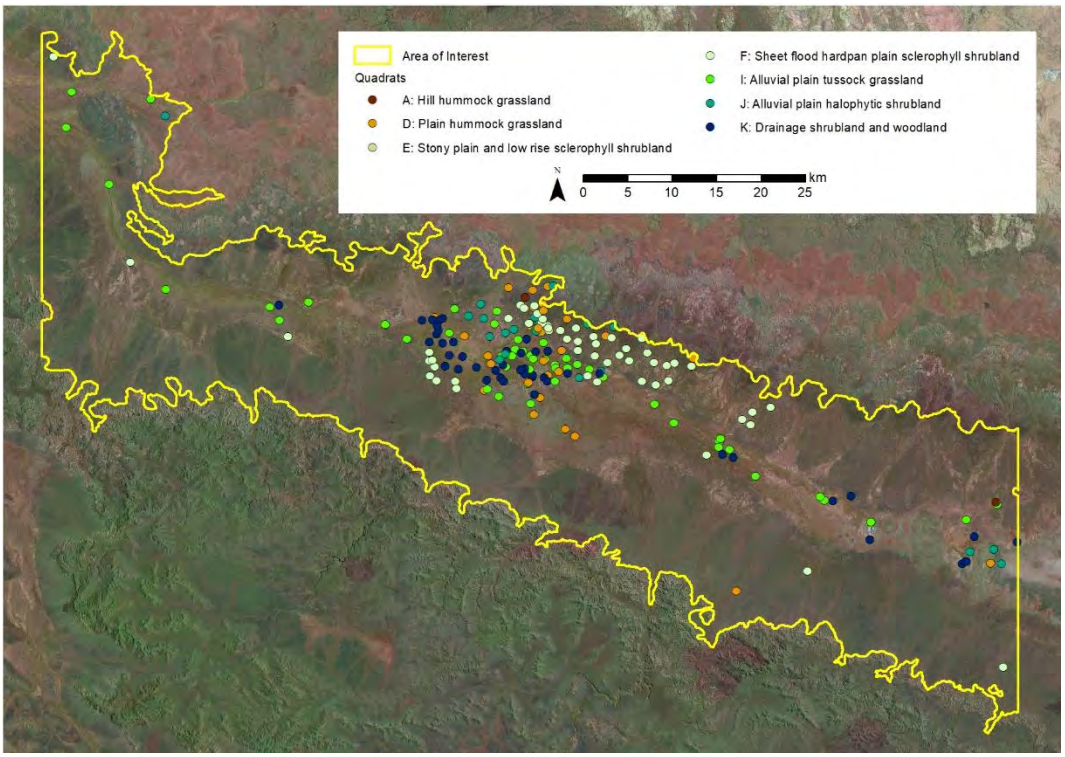


Figure 5: Distribution of Vegetation Quadrats across AOI

The site types in the AOI are listed in Table 6. A single quadrat classified as a Calcrete acacia cassia shrubland site type was grouped with other calcrete sites in the Plain hummock grassland site type group rather than analysed as a solitary example of the Stony plain and low rise sclerophyll shrubland site type group.

Table 6: Site Types and Site Type Group in AOI

Site Type Group Site Type/s	Quadrats
A: Hill hummock grassland	**2**
1. HSPG Hill spinifex grassland	1
2. HEHG Hill eucalypt spinifex grassland	1
D: Plain hummock grassland	**31**
5/6. PHSG/PSSG Plain hard/soft spinifex grassland	16
6. PSSG Plain soft spinifex grassland	1
8. CASG Calcrete spinifex grassland	13
13. CACS Calcrete acacia cassia shrubland*	1
F: Sheet flood hardpan plain sclerophyll shrubland	**54**
17. GMGW Grove mulga grassy woodland/shrubland	3
18. GMUW Grove mulga woodland/shrubland	51
I: Alluvial plain tussock grassland	**52**
28. APTG Alluvial plain tussock grassland	38
29. ARPG Alluvial plain Roebourne Plains grass grassland	2
33. SPSG Saline plain sporobolus grassland	8
34. SSTS Stony alluvial plain snakewood grassy shrubland	4
J: Alluvial plain halophytic shrubland	**23**
35. PSCS Plain snakewood shrubland with chenopod low shrubs	17
37. PSPS Plain samphire shrubland	6
K: Drainage shrubland and woodland	**49**
40. DESG Drainage spinifex grassland with eucalypt overstorey	3
42. DEAW Drainage eucalypt and acacia woodland/shrubland	46
Total	**211**

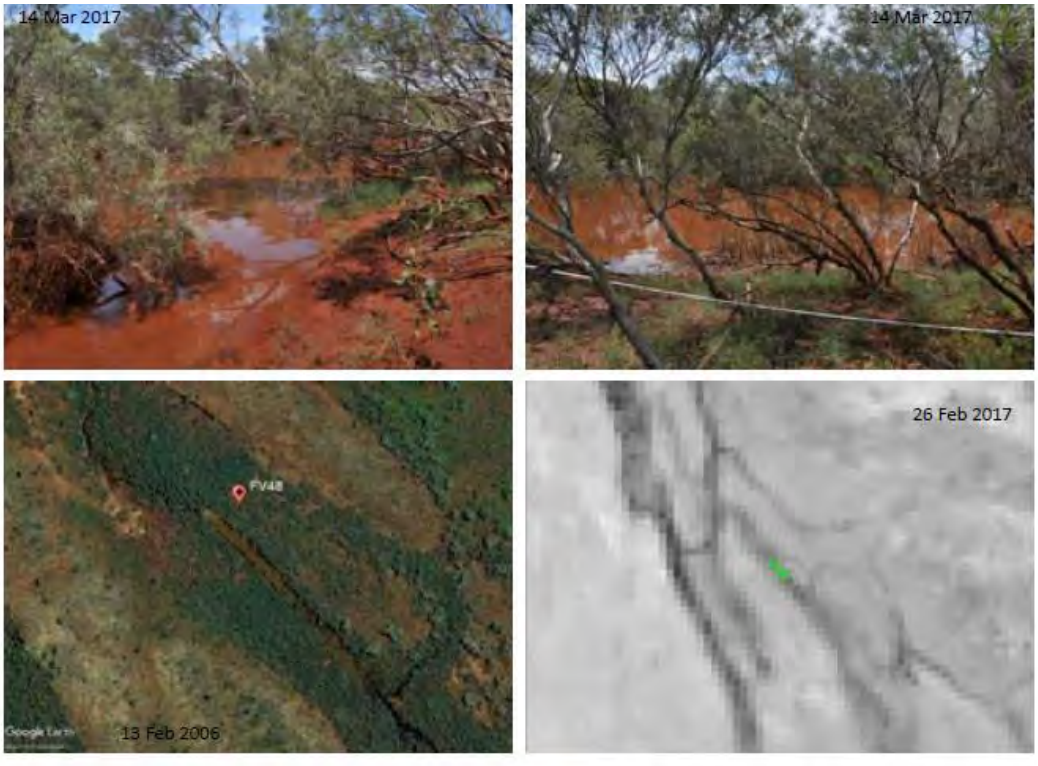
The quadrats in the AOI:

- do not include *Melaleuca argentea,* an obligate phreatophyte (Maia Environmental Consultancy, 2021);
- do not include *Eucalyptus camaldulensis,* a facultative phreatophyte (Maia Environmental Consultancy, 2021); but
- do include *Eucalyptus victrix,* a facultative phreatophyte (Maia Environmental Consultancy, 2021):
  - it is the dominant eucalypt species in the Fortescue River system and in the larger drainage areas in the hills in the north-eastern section of the Mulga East Iron Ore Project, which intersects the AOI (Maia Environmental Consultancy, 2021).
  - it occurred as scattered/isolated at quadrats classified as the 'Saline plain sporobolus grassland' site type;
  - it occurred as a dominant overstorey tree at quadrats classified as the 'Drainage spinifex grassland with eucalypt overstorey' site type (which generally occurs in areas that receive concentrated through flow of surface water) and 'Drainage eucalypt and acacia woodland/shrubland' site type (which lack a perennial grass layer and generally occurs in areas subject to fairly regular inundation).

Eucalyptus victrix

- is a facultative phreatophyte / vadophyte, that is low to moderately dependent on groundwater (Naaykens, 2020);
- occupies overlapping, but zones distinct from those of *Eucalyptus camaldulensis* in relation to water bodies, *Eucalyptus victrix* predominantly occurring in drier areas (Masini, 1988);
- is tolerant of long periods of drought but sensitive to prolonged inundation (Braimbridge, 2010);
- can occur in the absence of access to groundwater (Batini, 2009);
- growth and survival appears to be favoured by moving flood waters, and water tables below 2 metres (Masini, 1988);
- may at times draw at least some of its water needs from the capillary zone above the shallow groundwater table, especially when this rises rapidly after rain (Batini, 2009); and
- is a resilient tree, able to survive some flooding, rapid rises and falls of up to 10 m in the groundwater table and also extended periods of drought (Batini, 2009).

A single quadrat in the AOI was explicitly identified as groundwater-fed in the source documents. Site FV48(fauna)/FV48A(flora) (referred to as FV48 hereafter) was observed by Pinder *et al.* (2017) as having gradually flowing water without connection other surface water and was described as a groundwater-fed permanent marginally subsaline river pool with three stygofaunal species. The flora at the site is not necessarily accessing this groundwater as it is not indicative of groundwater dependence. There is an absence of phreatophytic tree species (the vegetation being Tall shrubland of *Melaleuca glomerata* over open low grassland of *Sporobolus mitchellii*), and there is low species diversity but several species more typical of the halophytic plant communities of the Fortescue Marsh are present (Pinder, et al., 2017). Pinder *et al.* (2017) site images are shown in Figure 6.



Site FV48. Un-named pool on braided section of Fortescue River on Mount Florence Station. Stygofaunal species in this pool, the presence of flow despite the channel being dry upstream, and elevated salinity indicate groundwater influence. Google Earth image © Google and Digital Globe 2017.

Figure 6: Fortescue Valley Wetland Biodiversity Survey Extract for Site FV48

3. RESULTS

3.1. Land Cover Classes

The average NDVI and NDMI values for site type groups over the drying period from May to December 2017 are shown in Figure 7 and Figure 8. Both indices reflect a drying trend until some reduction in the rate of drying after effective rainfall in November and increased growth/vigour after effective rainfall in December.

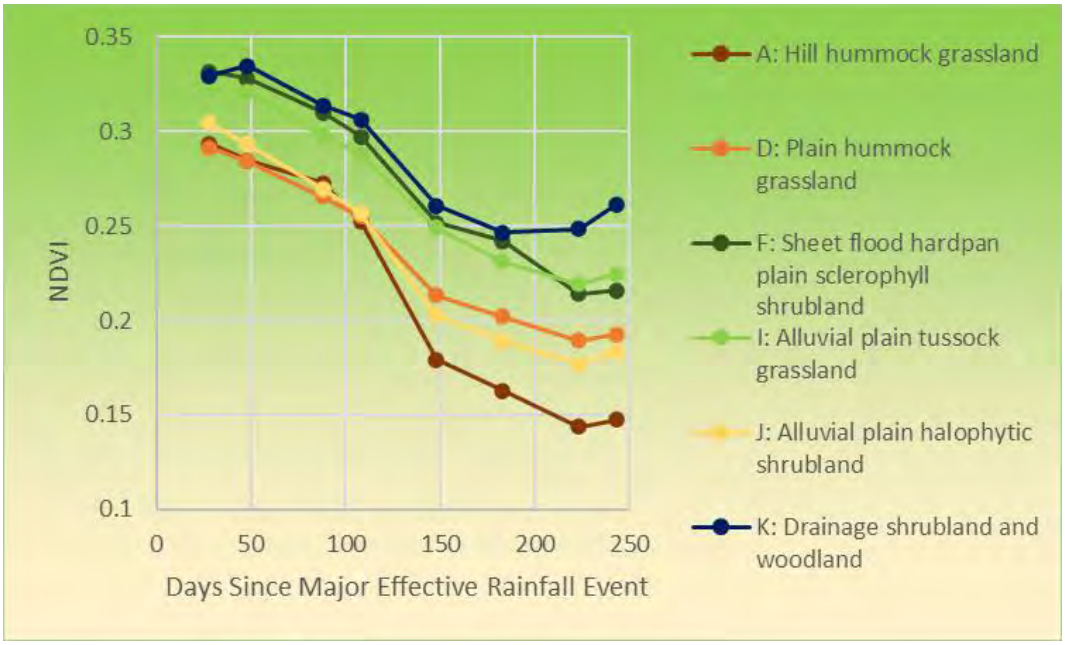


Figure 7: Average NDVI of Site Type Groups in Relation to Time Since Rain

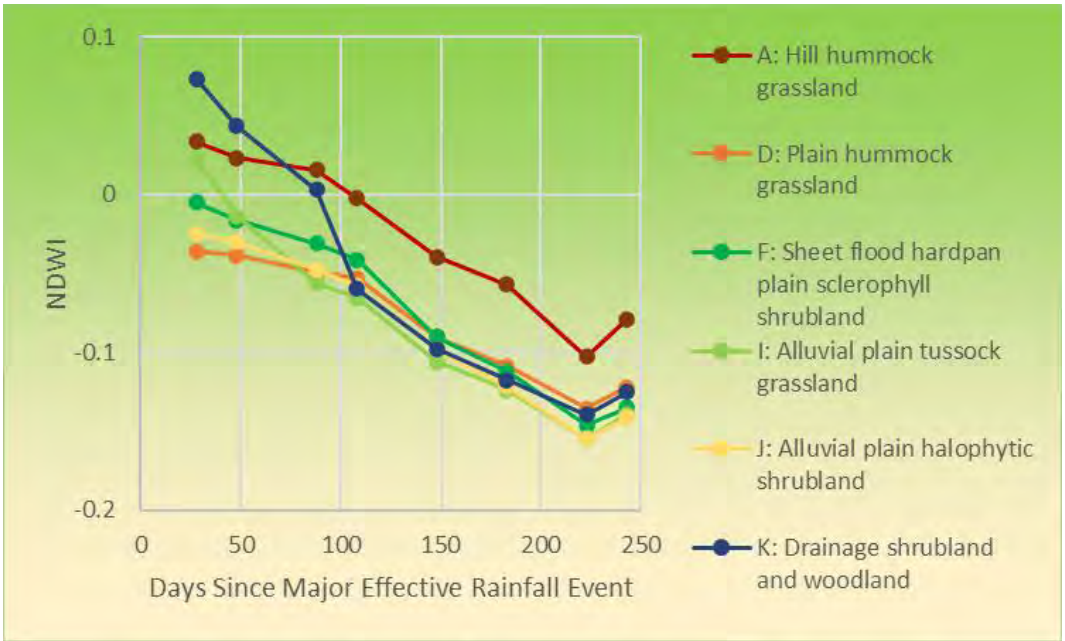


Figure 8: Average NDWI of Site Type Groups in Relation to Time Since Rain

The relatively high NDWI (moisture levels) of hill hummock grassland in Figure 8 may reflect localised anomalies (arising from localised ponding or proximity to vegetation boundaries etc) given data was only available from two quadrats for this site type group.

Figure 7 and Figure 8 indicate:

- larger separations between site type groups for NDVI than NDWI, which reflects NDVI being proportional to vegetation density; and
- NDVI and NDWI values increased after effective rain in December.

Land classes are produced from the GEM method with reference to how much NDVI and NDMI values change between wet and dry seasons. Figure 9 and Figure 10 show:

- maximum and minimum NDVI and NDWI values between May and December 2017 in relation to a 1:1 line, which points would fall on if the vegetation did not dry over time;
- drainagelines support the most vigour/dense vegetation and had the highest moisture levels, but all site type groups dried at similar rates (i.e. a similar distances from the 1:1 line indicating no change in plant density/vigour and moisture); and
- All vegetation site type groups could broadly be considered relatively 'fast drying' non-groundwater dependent vegetation.

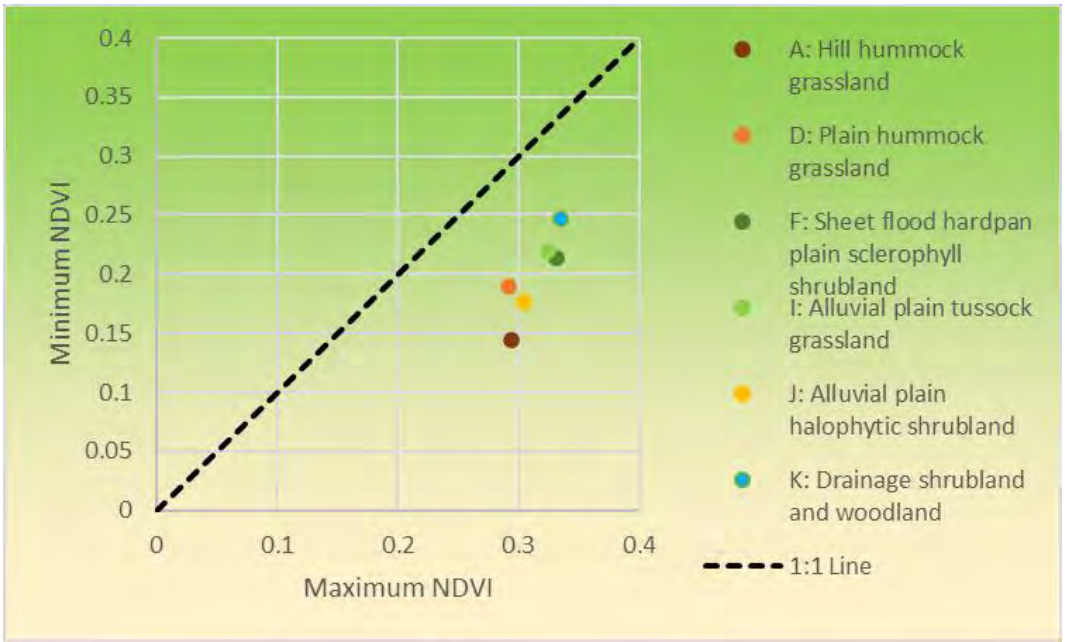


Figure 9: Maximum and Minimum NDVI for Site Type Group Averages

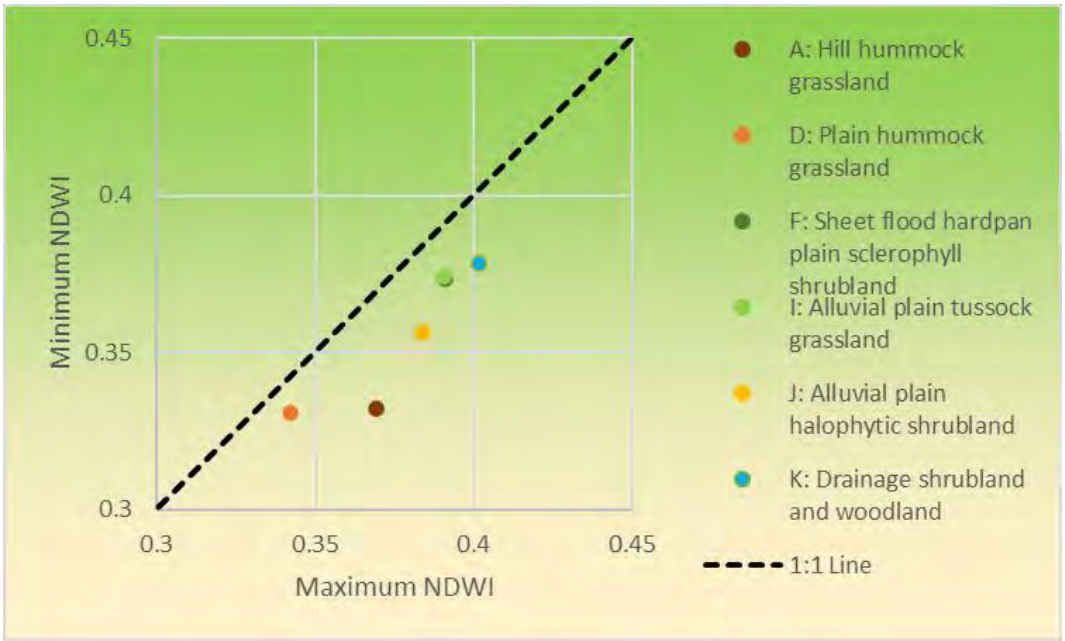


Figure 10: Maximum and Minimum NDWI for Site Type Group Averages

Figure 11 shows an indication of the extent and distribution of the drainageline vegetation generated from a nine (allowing for six site type groups, with three additional classes of bare ground, seasonally inundation and fire) cluster unsupervised classification of NDVI and NDMI values from May to December 2017.

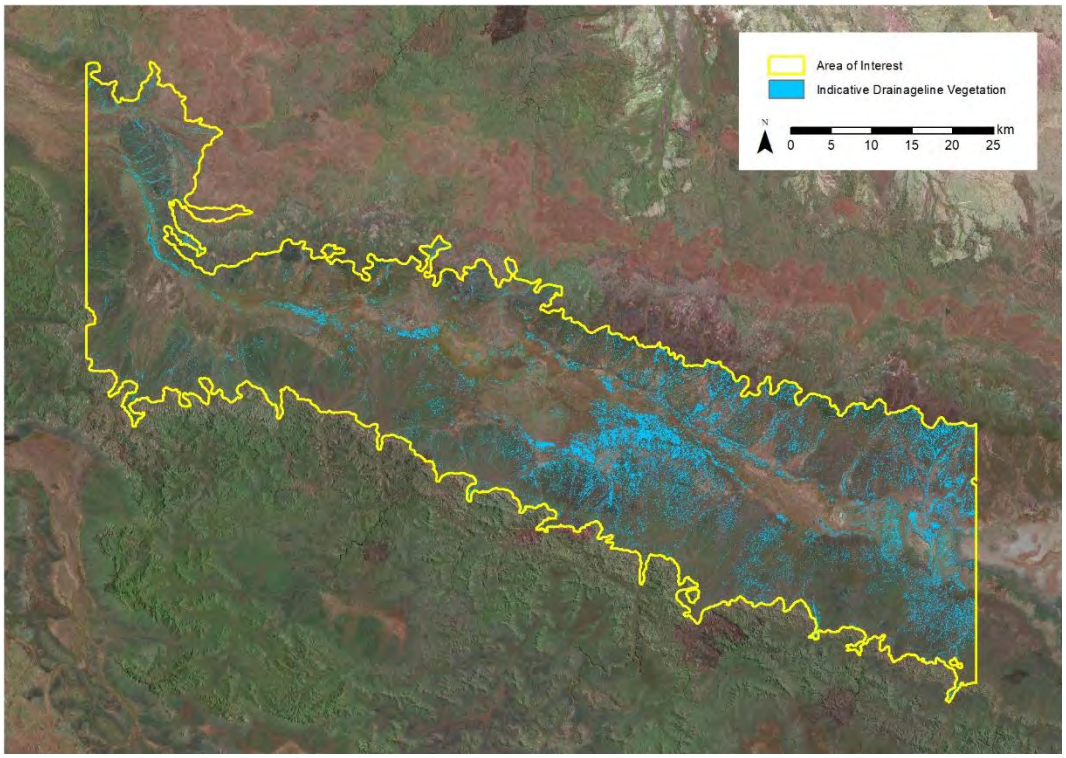


Figure 11: Indicative Map of Drainageline Vegetation

3.2. Sites of High and Stable NDVI

Maximum and minimum NDVI values for quadrats in relation to a 1:1 line, on which points would fall if the vegetation remained consistently dense/vigorous and moist, are shown in:

- Figure 12 for May to December 2017; and
- Figure 13 for May to October 2017.

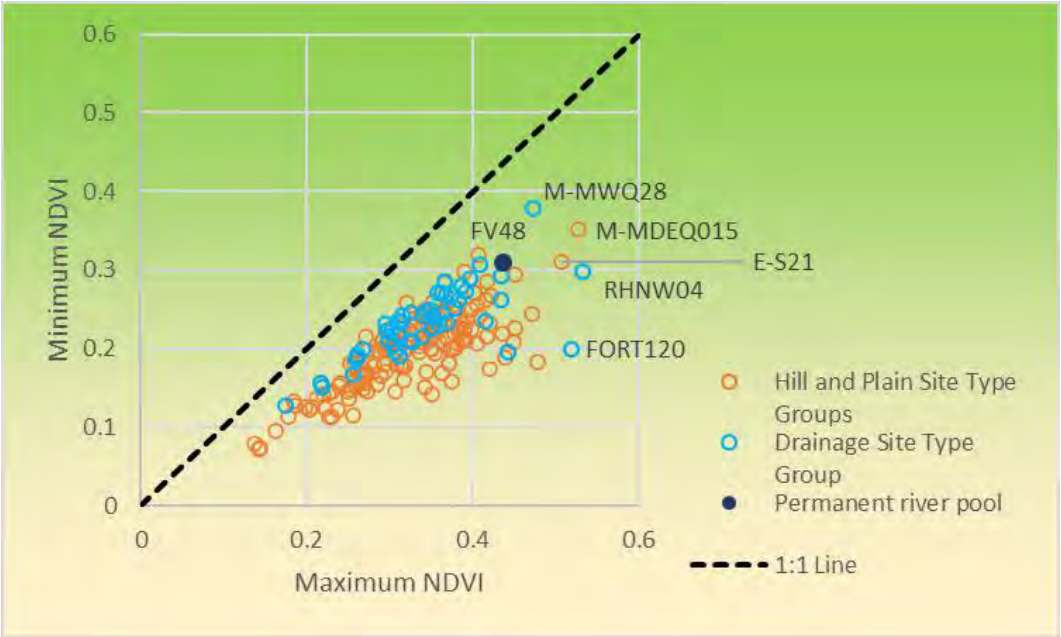


Figure 12: Maximum and Minimum NDVI for Quadrats between May and December

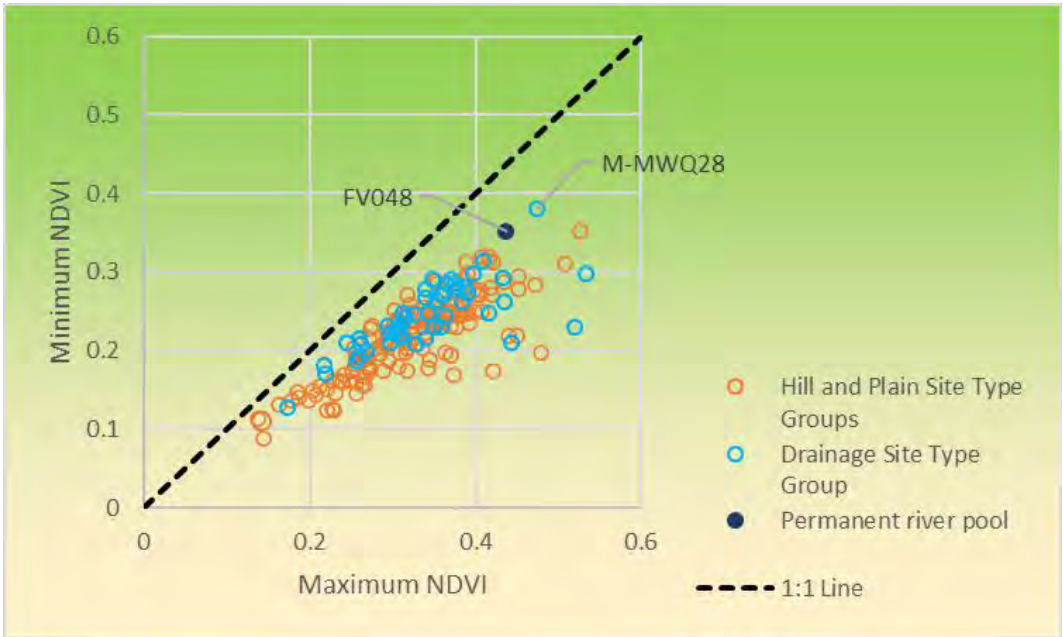


Figure 13: Maximum and Minimum NDVI for Quadrats between May and October

The 'permanent' river pool at site FV048 was detectable (separated from other drainageline sites) in the NDVI analysis in Figure 13 but not in Figure 12, but this may reflect the limitations of using a data within 50 metres of a point to represent as a more extensive vegetation unit, as high NDVI values persisted in nearby areas.

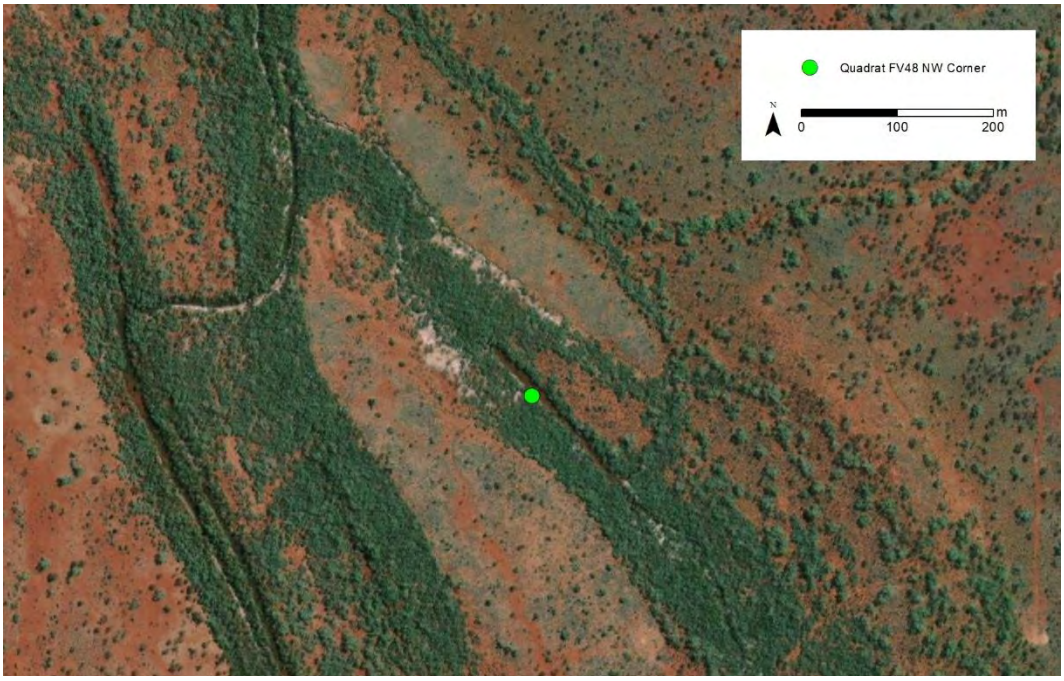


Figure 14: Aerial Image of Vegetation at FV48

The single quadrat with consistently dense/vigorous vegetation was M-MWQ28 (Figure 15). Floristic data was not available for the quadrat but Maia (2021) classified the site as AdEvWL vegetation type, Low Open Woodland to Low Woodland of *Acacia distans* and *Eucalyptus victrix* sometimes with a Tall Sparse Shrubland of *Acacia stenophylla* or *Acacia tetragonophylla* and a Shrubland to a Sparse Shrubland of *Duma florulenta.*

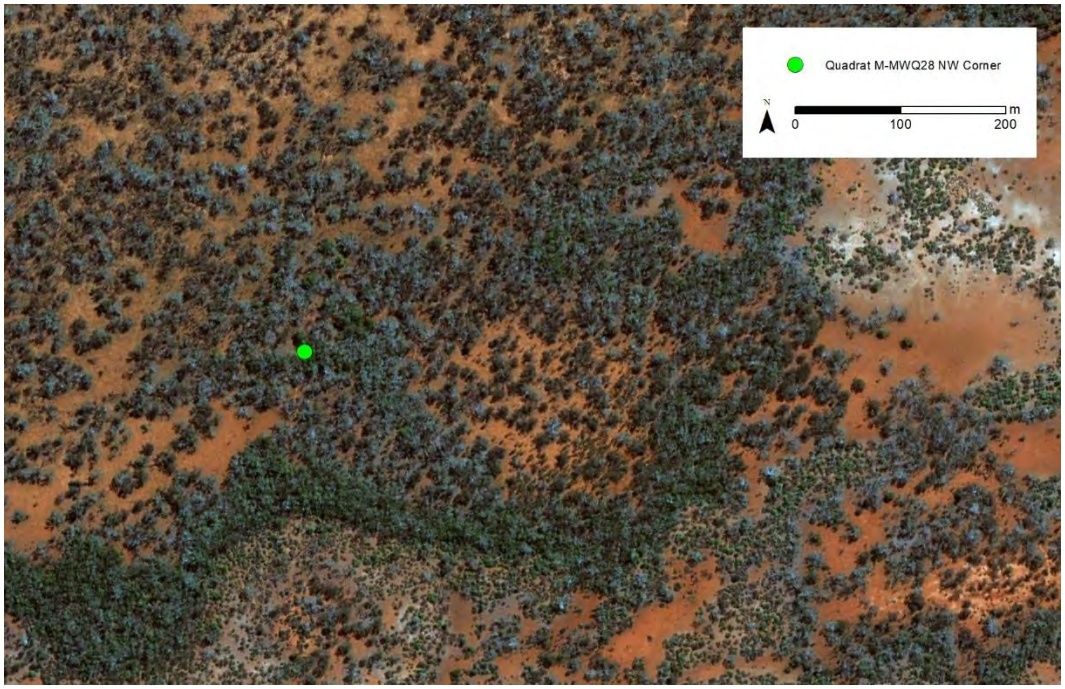


Figure 15: Aerial Image of Vegetation at M-MWQ28

Figure 16 shows NDVI decline reflect a drying trend for quadrats M-MWQ28 and FV48:

- until stabilisation after effective rainfall in November, and increased growth/vigour after effective rainfall in December, for Quadrat M-MWQ28; and
- continuing declines after rainfall in November and December for Quadrat FV48.

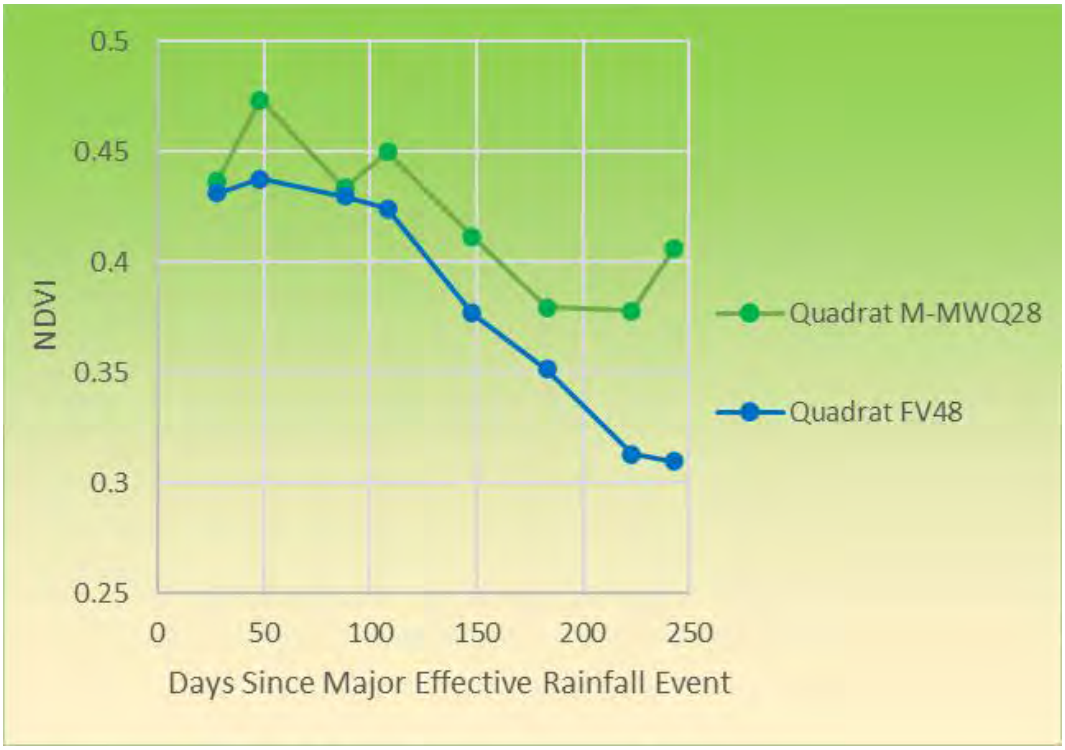


Figure 16: NDVI for Quadrats M-MWQ28 and FV48 in Relation to Time Since Rain

Four sites with high seasonal NDVI variability in Figure 12 appear to have values driven by tussock grasses with seasonal vigour:

- M-MDEQ015 was classified by Maia (2021) as vegetation type MSL2, Sparse to Open mixed Tall Shrubland mainly of *Acacia synchronicia*, *A. tetragonophylla*, and *Melaleuca glomerata* over a mixed Low Shrubland mainly of *Indigofera monophylla*, *Solanum lasiophyllum* and *Stemodia grossa* and either a Sparse Tussock grassland of *Eragrostis desertorum* or a *Hummock* Grassland of *Triodia epactia*;
- E-S21 was classified by Maia (2021) as vegetation type ASL1, Tall Sparse to Open mixed Shrubland mainly of *Acacia synchronicia, Acacia tetragonophylla, Acacia xiphophylla* with a mixed Sparse Chenopod Shrubland mainly of *Sclerolaena densiflora, Sclerolaena cuneata* and *Sclerolaena costata* and Isolated mixed Tussock Grasses mainly of *Sporobolus australasicus, Enneapogon polyphyllus* and *Dactyloctenium radulans*;
- RHNW04 was described in the Pilbara Biological Survey (DBCA, 2021) as Scattered Trees of *Eucalyptus victrix* over Low Open Woodland of *Eucalyptus victrix* over Scattered Tall Shrubs of *Acacia sclerosperma* & *Hakea lorea* over Open Shrubland of *Acacia sclerosperma, Acacia tetragonophylla, Vachellia farnesiana* over Closed Tussock Grassland of *Eriachne benthamii;* and
- FORT120 was described by Markey (2017) as Isolated plants of mostly senesced *Acacia tetragonophylla* and *Acacia synchronicia*, over mid-dense shrubland of *Eremophila spongiocarpa*, *Tecticornia indica* subsp. *bidens*, *Paspalidium* aff *jubiflorum*, and occasional *Duma florulenta*, over dense low grassland and herbfield of *Cullen cinereum*, *Eragrostis dielsii* and *Flaveria trinervis*.; and classified as part of vegetation group IB: *Eucalyptus victrix, Acacia synchronicia*, lignum (Duma) and samphire shrublands and woodlands.

3.3. Sites of High and Stable NDWI

Maximum and minimum NDWI values for quadrats in relation to a 1:1 line, on which points would fall if the vegetation remained consistently dense/vigorous and moist, are shown in:

- Figure 17 for May to December 2017; and
- Figure 18 for May to October 2017.

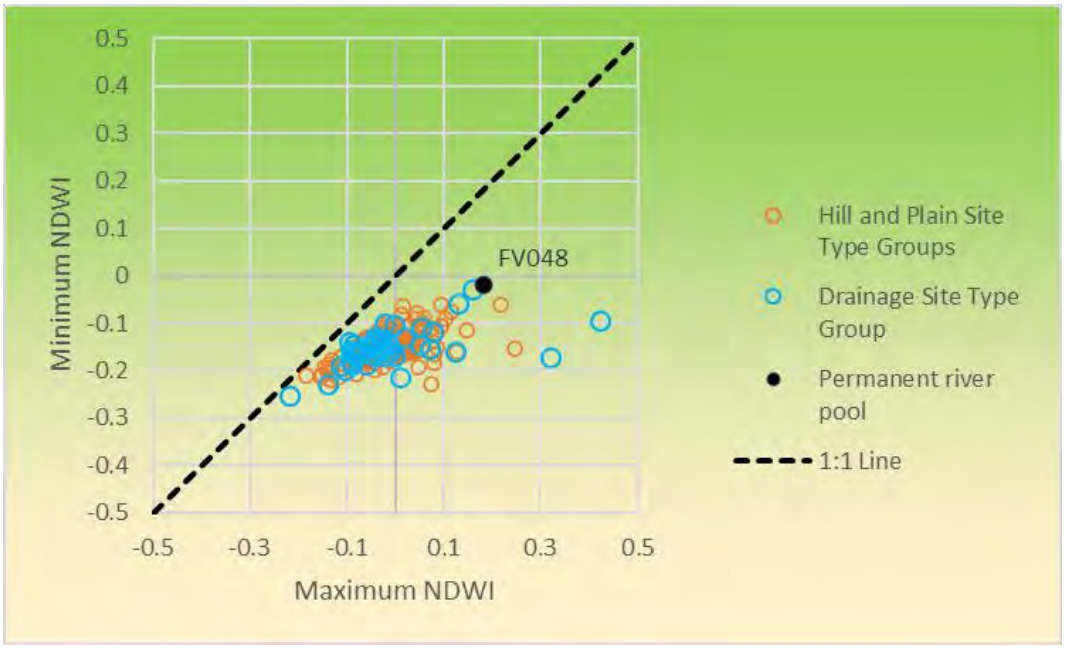


Figure 17: Maximum and Minimum NDWI for Quadrats between May and December

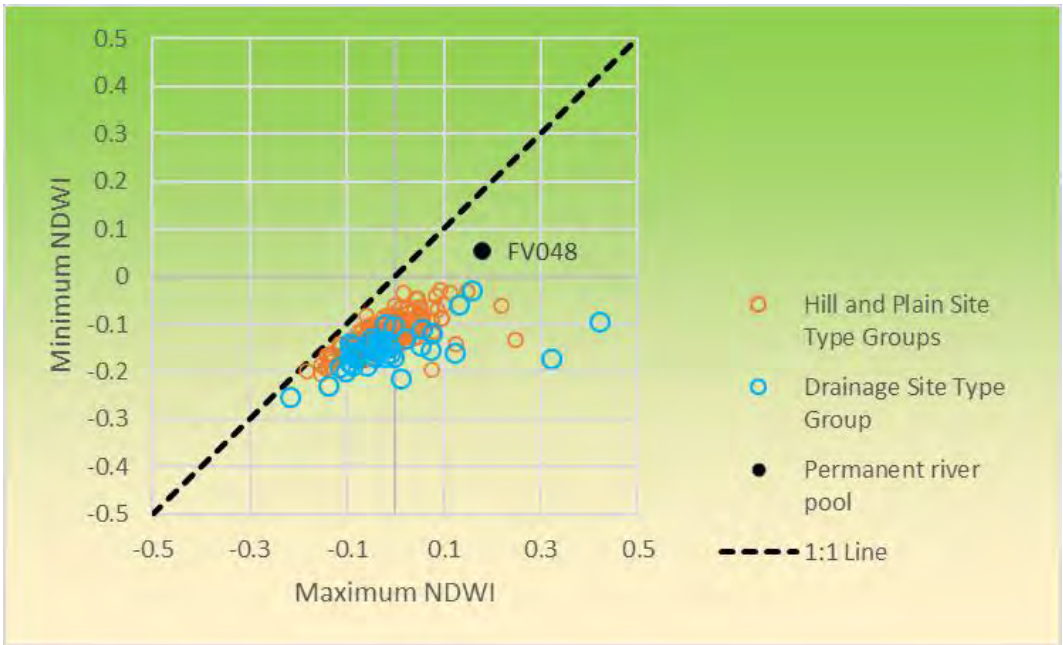


Figure 18: Maximum and Minimum NDWI for Quadrats between May and October

The 'permanent' river pool at site FV048 was detectable (separated from other drainageline sites) in the NDWI analysis in Figure 18 but not in Figure 17, but this may reflect the limitations of using a data within 50 metres of a point to represent as a more extensive vegetation unit, as high NDWI values persisted in nearby areas.

Figure 19 shows the decline in NDWI for Quadrat FV48 continues until after rainfall in December.

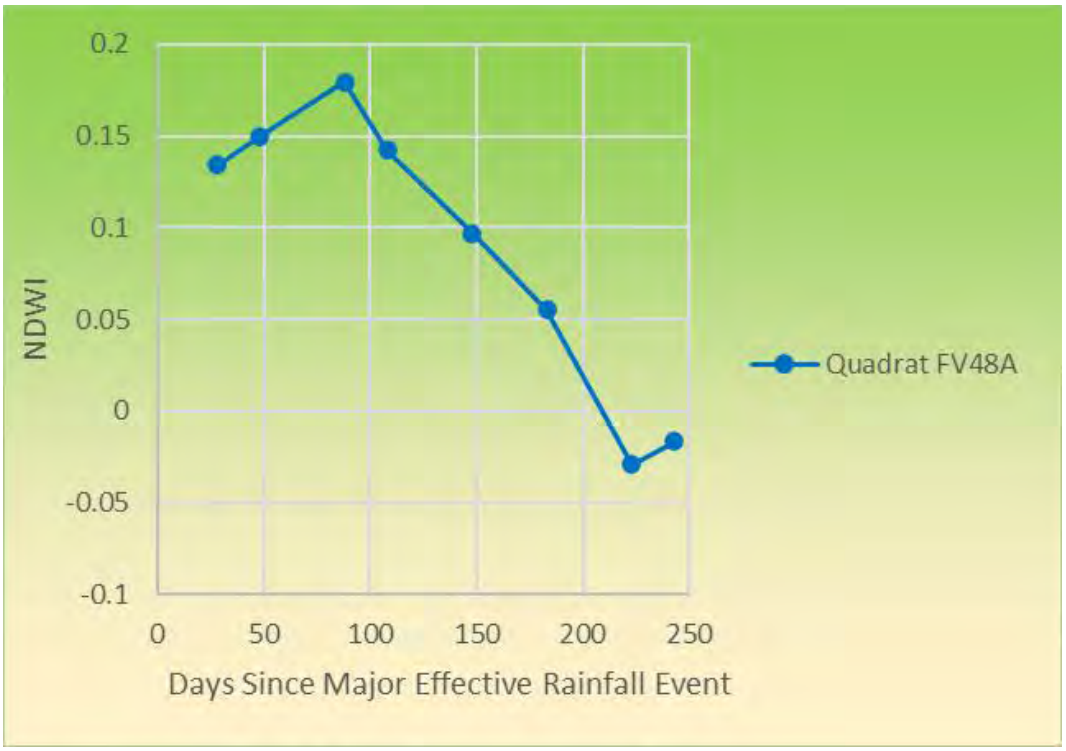


Figure 19: NDWI for Quadrat FV48 in Relation to Time Since Rain

4. DISCUSSION

Areas of potential Groundwater Dependent Vegetation (GDV) can be identified through their exceeding of multispectral index values for non-groundwater dependent vegetation. Quadrat FV48, the single quadrat in the AOI that was explicitly identified as groundwater-fed in the source documents mentioned, can be separated from almost all quadrats by the thresholds of:

- October NDWI > 0
- October NDVI > 0.35; and
- May NDVI - October NDVI <0.1

Applying these thresholds to identify sites at least as consistently wet as quadrat FV48 identifies the areas covering a total of approximately 30 hectares of shown in Figure 20, which also shows M-MWQ28 as a site warranting further examination as it is an outlier of relatively high and stable NDVI that may support *Eucalyptus victrix*.

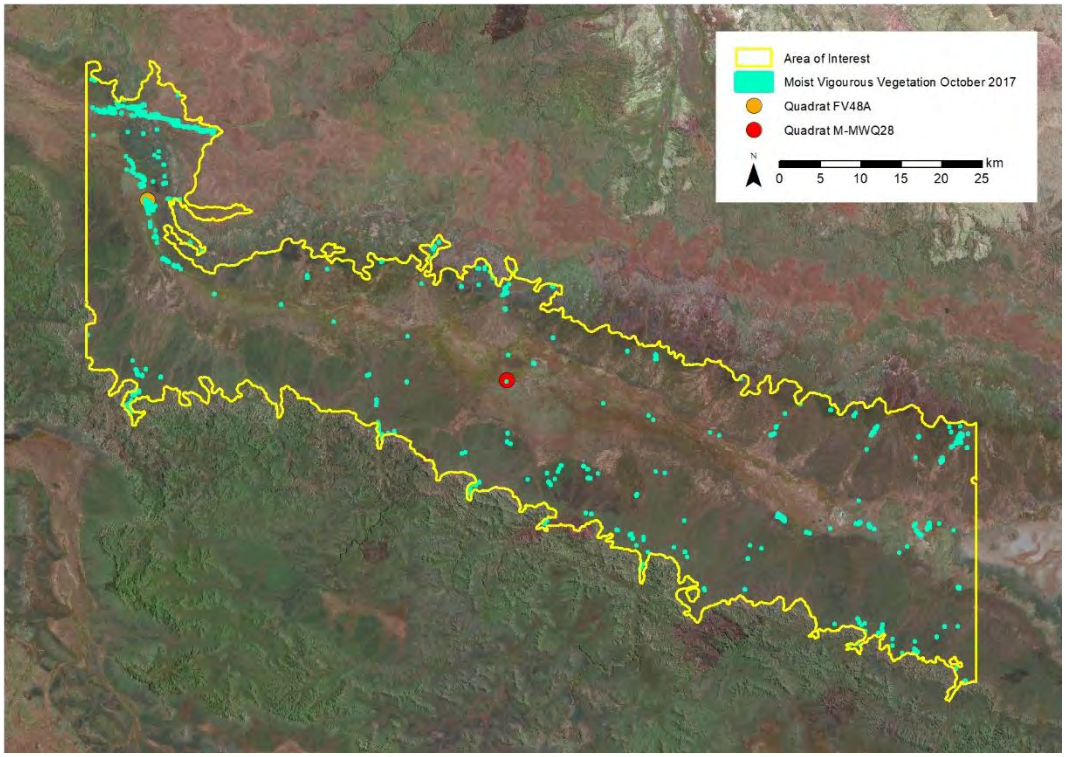


Figure 20: Areas of Stable NDVI, and High NDVI and NDWI in October

Applying these thresholds to November NDVI and NDWI datasets, when minimum values for these indices were recorded (prior to increases in response to rain in December) identifies the areas most likely to remain vigorous/dense and moist all year round and therefore have the highest potential to be groundwater dependent. These areas cover the 29 hectares shown in Figure 21. The relatively large areas along the east-west Hooley Creek and north-south Fortescue River in the northwest of the AOI are symbolised in Figure 22 without borders to provide a more precise visual indication of extents.

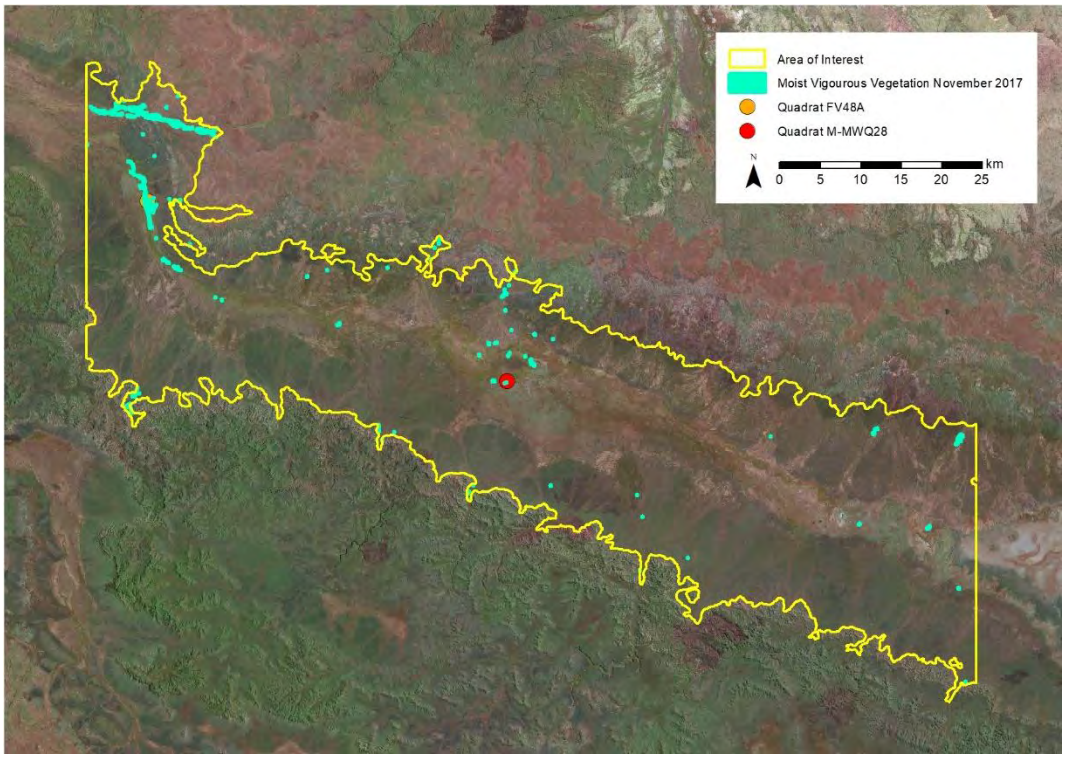


Figure 21: Areas of Stable NDVI and High NDVI and NDWI in November

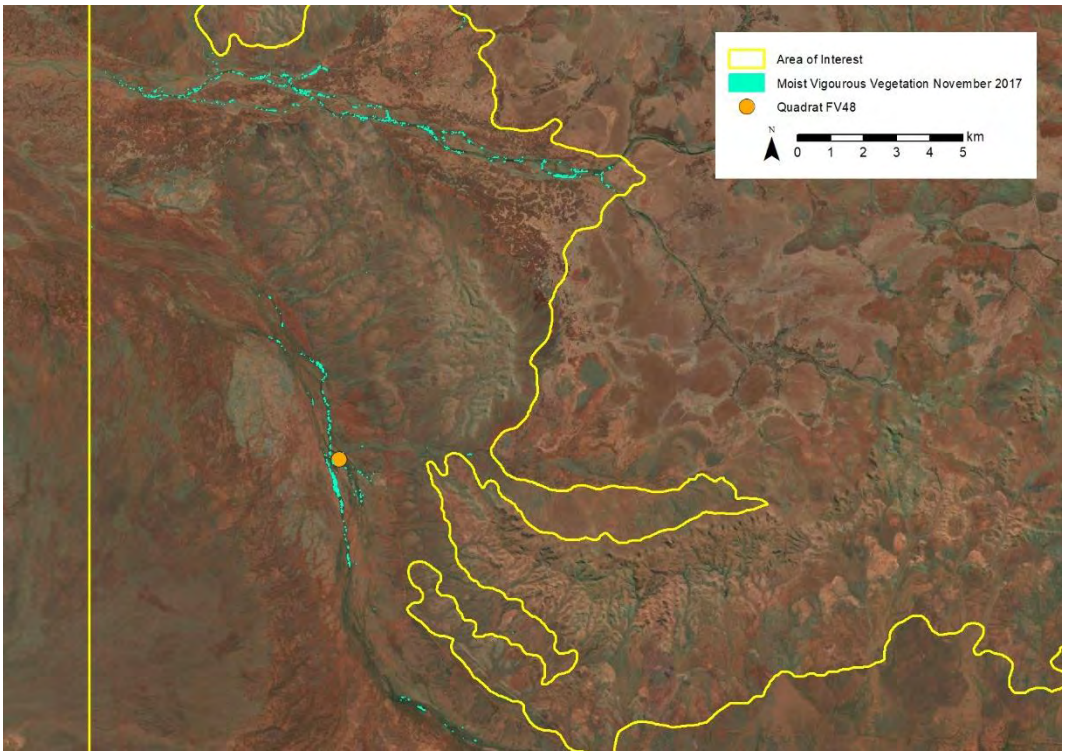


Figure 22: Areas of Stable NDVI and High NDVI and NDWI in AOI Northwest in November

Multispectral indices indicate drying of the 'permanent' river pool at site FV048, but Figure 22 indicates high NDVI and NDWI values persisted in nearby areas which leads to the interpretation that whilst the pool contracts it is not necessarily impermanent or that groundwater becomes disconnected from the surface during dry seasons.

5. CONCLUSIONS AND RECOMMENDATIONS

Data from 211 vegetation quadrats in the AOI were consolidated into a single classification of six broad vegetation groups that can all be broadly considered relatively 'fast drying' and non-groundwater dependent. *Eucalyptus victrix,* a facultative phreatophyte that can utilise but does not require access to groundwater, was recorded over significant portions of the AOI but *Melaleuca argentea* and *Eucalyptus camaldulensis,* trees that are associated with greater groundwater availability, were not recorded in quadrats.

A single quadrat in the AOI was explicitly identified as groundwater-fed in the source documents. Site FV48 has been observed as having gradually flowing water without connection other surface water and described as a groundwater-fed permanent marginally subsaline river pool with three stygofaunal species. Floristic data in the absence of these observations would not lead to the identification of this site as groundwater dependent due to absence of phreatophytic tree species. Multispectral analysis indicated drying of this 'permanent' river pool, but high NDVI and NDWI values persisted in nearby areas which leads to the interpretation that whilst the pool may become contract it is not necessarily impermanent or that groundwater becomes disconnected from the surface during dry seasons.

A quadrat with unusually dense/vigorous vegetation was identified in the multispectral analysis and field observations are likely required to explain whether this is associated with groundwater availability or other factors such as localized surface water impedance. Quadrat M-MWQ28 was classified as a *Acacia distans* and *Eucalyptus victrix* woodland, but more detailed floristic or site data was not available.

Areas that could be further investigated for potential Groundwater Dependent Vegetation (GDV) were identified on the basis of them exceeding multispectral index thresholds for non-groundwater dependent vegetation in the AOI. These areas cover 29 hectares, 0.01% of the AOI, with more extensive large areas along Hooley Creek and the Fortescue River in the northwest of the AOI. Further refinement of the multispectral analysis can be undertaken such as through the removal of isolated individual areas representing single 10 m x 10 m pixels in the datasets and further examination of ranges of indices in wetter areas, additional field observations in potential GDV areas should be obtained to direct this.

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APPENDIX R
RELATIONSHIPS BETWEEN TRANSPIRATION AND SOIL MATRIC POTENTIAL

The relationship between plant transpiration and soil water content involves a trade-off between carbon fixation (i.e. photosynthesis) and water loss via leaf stomata. When the air and soil are dry, photosynthesis is sacrificed in favour of reduced water loss. Sperry et al. (2016) have developed and applied a 'supply - demand' theory of water limited stomatal regulation for describing and quantifying this trade-off process, as described in Figure A below:

Sperry et al. (2016) tested their model against nine published data sets of ecophysiological measurements from a range of plant species/growth forms. This data comprised soil type, species vulnerability curves, the maximum hydraulic conductance (kmax) of plant conductive tissues (integrated root – stem- leaf), and a time course of predawn leaf water potential (LWP) and midday LWP, atmospheric vapour pressure deficit (D), and stomatal conductance (G) measured on individual trees and on sunny days. All data sets included major drought events. Note that G is directly proportional to transpiration, with the proportionality relationship determined by atmospheric conditions. Varying responses of G to declining soil moisture (units of matric potential) were related to atmospheric conditions and plant hydraulic traits as depicted in Figure B. Inputs that increased G relative to the default curve were:

- greater continuum kmax (curve 2),
- a more resistant sigmoid vulnerability curve (curve 3), and
- a lower D (curve 12; 0.5 kPa vs default of 1.0 kPa).

Note that increasing Gmax had no effect because G was already below Gmax in the default case.

Inputs that decreased G were:

- reduced kmax (curve 4),
- a weaker sigmoid vulnerability curve (curve 5),
- the exponential vulnerability curve (curve 6),
- previous exposure to drought (curve 8),
- greater D (curve 13; 4 kPa),
- and lower Gmax (curve 10).

In drying soil, an increase in the average rhizosphere resistance also caused more closure (curve 11).

Collectively, the set of curves shown in Figure B captures a broad range of different species x soils x atmospheric conditions combinations. For parameterisation of the Ecohydrological Water Balance (EWB) model, the y-axis of Figure B was normalised to maximum G.

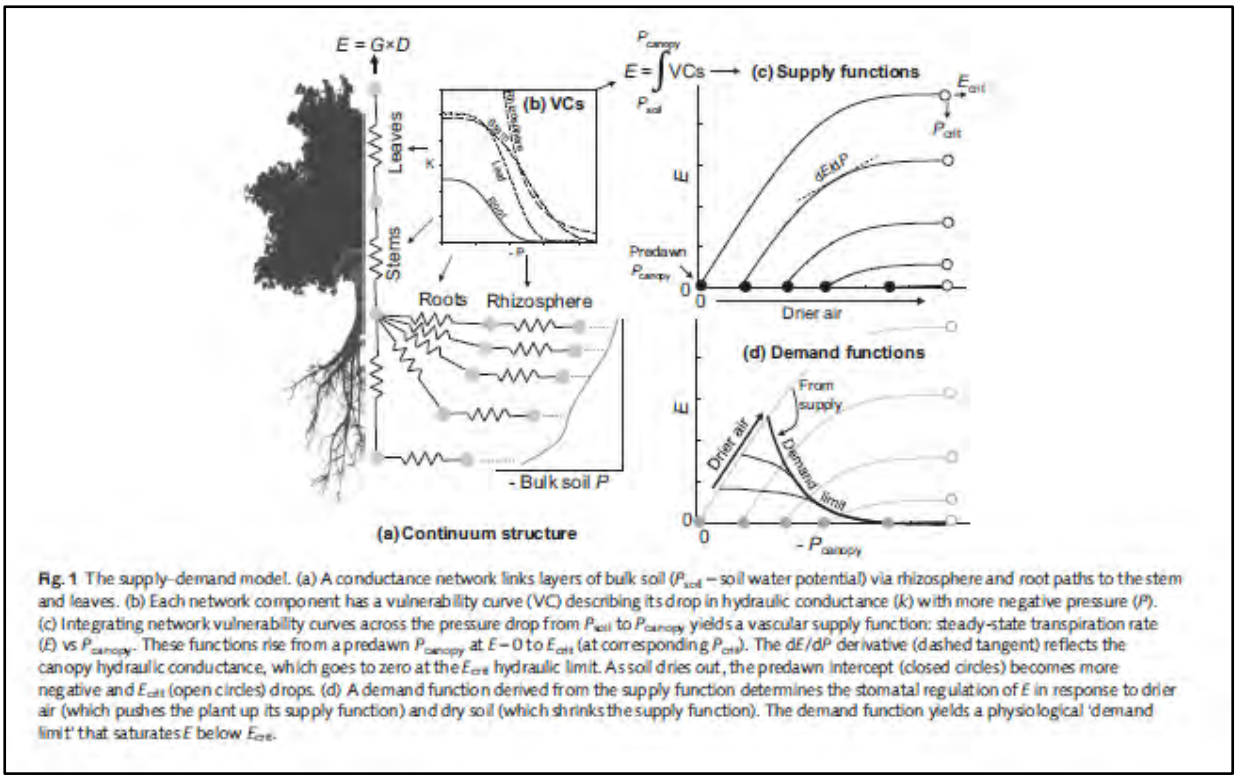


Fig. 1 The supply–demand model. (a) A conductance network links layers of bulk soil (P_{soil} – soil water potential) via rhizosphere and root paths to the stem and leaves. (b) Each network component has a vulnerability curve (VC) describing its drop in hydraulic conductance (k) with more negative pressure (P). (c) Integrating network vulnerability curves across the pressure drop from P_{soil} to P_{canopy} yields a vascular supply function: steady-state transpiration rate (E) vs P_{canopy}. These functions rise from a predawn P_{canopy} at $E = 0$ to E_{crit} (at corresponding P_{crit}). The dE/dP derivative (dashed tangent) reflects the canopy hydraulic conductance, which goes to zero at the E_{crit} hydraulic limit. As soil dries out, the predawn intercept (closed circles) becomes more negative and E_{crit} (open circles) drops. (d) A demand function derived from the supply function determines the stomatal regulation of E in response to drier air (which pushes the plant up its supply function) and dry soil (which shrinks the supply function). The demand function yields a physiological 'demand limit' that saturates E below E_{crit}.

Figure A Plant water use regulation 'supply and demand' model (reproduced from Sperry et al. 2016)

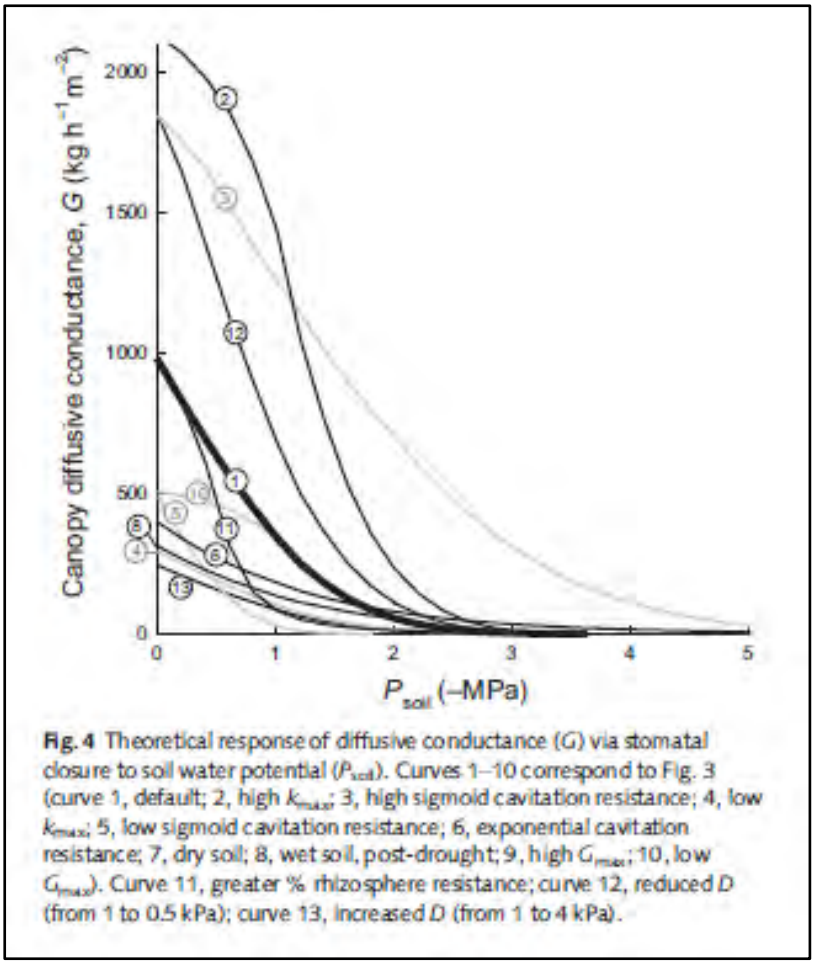


Fig. 4 Theoretical response of diffusive conductance (G) via stomatal closure to soil water potential (P_{soil}). Curves 1–10 correspond to Fig. 3 (curve 1, default; 2, high k_{max}; 3, high sigmoid cavitation resistance; 4, low k_{max}; 5, low sigmoid cavitation resistance; 6, exponential cavitation resistance; 7, dry soil; 8, wet soil, post-drought; 9, high G_{max}; 10, low G_{max}). Curve 11, greater % rhizosphere resistance; curve 12, reduced D (from 1 to 0.5 kPa); curve 13, increased D (from 1 to 4 kPa).

Figure B Stomatal response to soil moisture deficit (reproduced from Sperry et al. 2016)

Fundamental aspects of the 'supply-demand' model have been reaffirmed in numerous subsequent studies and meta-analyses of plant hydraulic regulation. Carminati and Javaux (2020) developed a generalised model of relationships between transpiration rate E ($cm^3\ s^{-1}$), bulk soil water potentials (ψsoil; MPa) and leaf water potentials (ψleaf, MPa) as shown in Figure C. As stated in their paper:

'Presenting the results as the surface E(ψsoil,ψleaf) gives fundamental insights into soil and plant hydraulics and reconciles the views of plant physiologists (Figure 3C) and soil scientists (Figure 3B) on soil–plant water relations. The surface E(ψsoil,ψleaf) represents the physically possible hydraulic states of the plant. When ψsoil and ψleaf are equal, there is no gradient in water potential to drive water flow from the soil to the leaves and transpiration is null. When ψsoil is high (i.e., in wet soil), increasing E results in a linear decrease in ψleaf. In wet soil, the surface starts to deviate from the linear relation only at high transpiration rates due to the decrease of xylem conductivity because of cavitation. Whereas, as the soil dries out, the surface already starts to deviate from the linear relation at moderate transpiration rates because of the decreasing soil hydraulic conductivity.

Xylem embolism determines the shape of E(ψsoil,ψleaf) at high transpiration rates in wet soils, while belowground processes (namely rhizosphere hydraulic conductivity and root length) control its shape under dry conditions.

At any soil water potential, there is a critical E at which the surface deviates from the linear relation. We define a stress onset limit (SOL), which divides the surface in two zones (red line in Figure 3A). The SOL is the point at which the slope of E(ψleaf,ψsoil) at constant ψsoil reaches 80% of its maximum value. In the linear zone (green zone in Figure 3A), neither the soil nor the xylem are subject to reductions in hydraulic conductivity. In the nonlinear zone (in brown in Figure 3A), the loss of xylem or rhizosphere hydraulic conductivity generates an additional resistance to flow causing a large drop in leaf water potential for a slight increase in transpiration rate. Note that the transition between the linear and nonlinear zones is continuous.

Figure 3 shows an exemplary surface and SOL in the (E,ψsoil) and (E,ψleaf) planes. From the leaf perspective (Figure 3A), the SOL displays a similar shape to universal stomatal conductance responses of vascular plants. From the soil perspective (Figure 3B), the SOL is consistent with well-accepted observations of nonlinear decreases of E with decreasing ψsoil. Given the marked nonlinearity of E(ψsoil,ψleaf), an optimal strategy of plants undergoing soil drying is to promptly close the stomata while the SOL is approached. To accomplish this function, stomata should be able to sense the change in leaf water potential in relation to a change in transpiration. A mechanism that enables stomata to maintain plants in the linear zone of the hydraulic surface independently of environmental and soil conditions is not known and, thus is an outstanding question.'

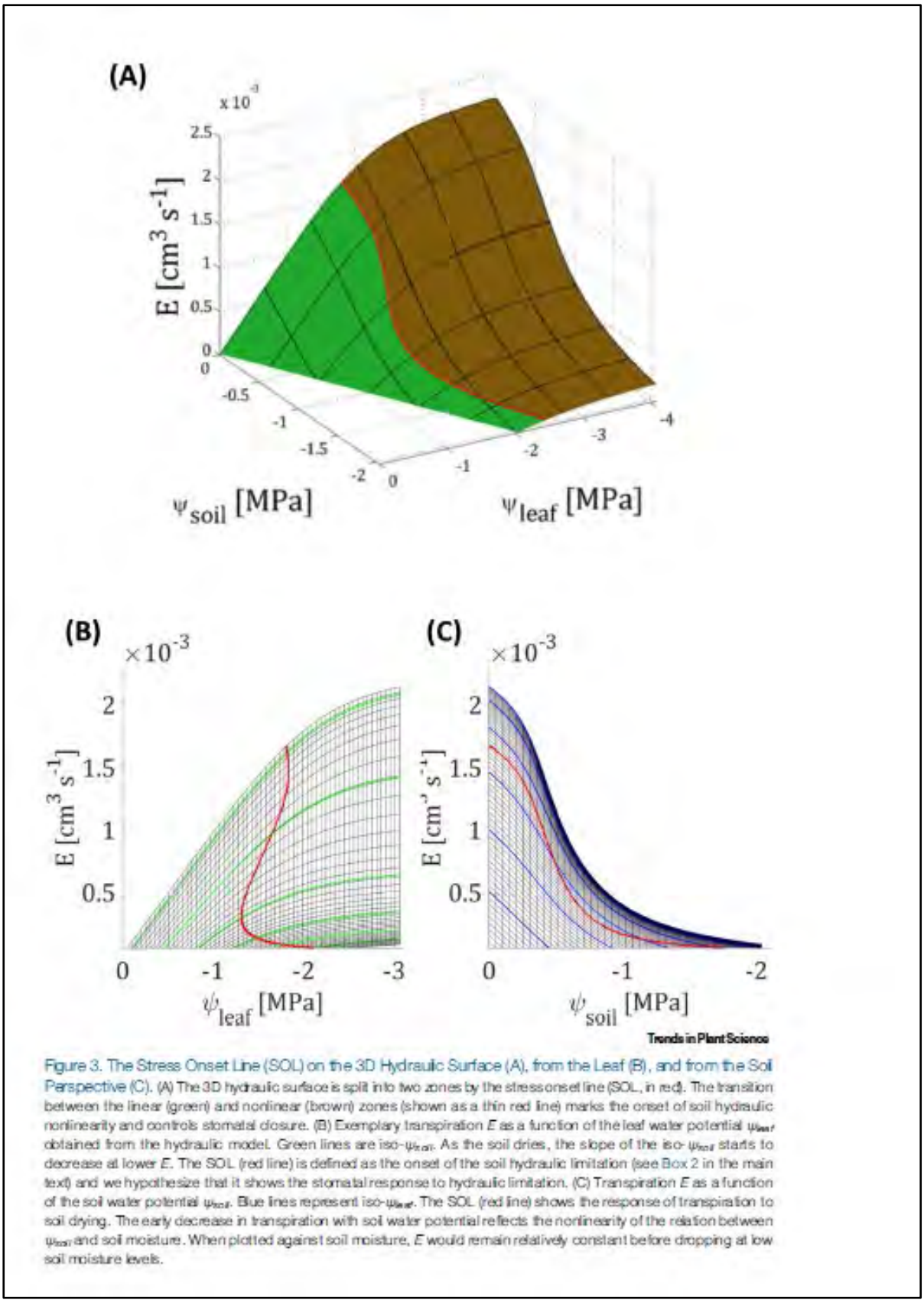


Figure 3. The Stress Onset Line (SOL) on the 3D Hydraulic Surface (A), from the Leaf (B), and from the Soil Perspective (C). (A) The 3D hydraulic surface is split into two zones by the stress onset line (SOL, in red). The transition between the linear (green) and nonlinear (brown) zones (shown as a thin red line) marks the onset of soil hydraulic nonlinearity and controls stomatal closure. (B) Exemplary transpiration E as a function of the leaf water potential ψ_{leaf} obtained from the hydraulic model. Green lines are iso-ψ_{soil}. As the soil dries, the slope of the iso-ψ_{soil} starts to decrease at lower E. The SOL (red line) is defined as the onset of the soil hydraulic limitation (see Box 2 in the main text) and we hypothesize that it shows the stomatal response to hydraulic limitation. (C) Transpiration E as a function of the soil water potential ψ_{soil}. Blue lines represent iso-ψ_{leaf}. The SOL (red line) shows the response of transpiration to soil drying. The early decrease in transpiration with soil water potential reflects the nonlinearity of the relation between ψ_{soil} and soil moisture. When plotted against soil moisture, E would remain relatively constant before dropping at low soil moisture levels.

Figure C Generalised model of relationships between transpiration rate, soil water potential and leaf water potential (reproduced from Carminati and Javaux, 2020)

APPENDIX S
TREE STEM MEASUREMENT DATA

Plot ID	Landform	Tree	Species Code	Stem 1	Stem 2	Stem 3	Stem 4	Stem 5	Stem 6	Stem 7	SUM (mm) all stem dia	Dequiv. (mm) (for all stems)	Basal area (m2)
A_North_1	Claypan	1	Ev	155	0	0	0	0	0	0	155	155	0.019
A_North_1	Claypan	2	Ev	139	0	0	0	0	0	0	139	139	0.015
A_North_1	Claypan	3	Ev	107	0	0	0	0	0	0	107	107	0.009
A_North_1	Claypan	4	Ev	112	0	0	0	0	0	0	112	112	0.010
A_North_1	Claypan	5	Ev	105	64	0	0	0	0	0	169	123	0.012
A_North_1	Claypan	6	Ev	124	0	0	0	0	0	0	124	124	0.012
A_North_10	Claypan	1	Ev	470	0	0	0	0	0	0	470	470	0.173
A_North_10	Claypan	2	Ev	609	0	0	0	0	0	0	609	609	0.291
A_North_10	Claypan	3	Ev	460	0	0	0	0	0	0	460	460	0.166
A_North_10	Claypan	4	Ev	521	430	355	0	0	0	0	1306	763	0.457
A_North_10	Claypan	5	Ev	1037	0	0	0	0	0	0	1037	1037	0.845
A_North_10	Claypan	6	Ev	277	0	0	0	0	0	0	277	277	0.060
A_North_10	Claypan	7	Ev	500	0	0	0	0	0	0	500	500	0.196
A_North_10	Claypan	8	Ev	508	0	0	0	0	0	0	508	508	0.203
A_North_2	Claypan	1	Ev	766	0	0	0	0	0	0	766	766	0.461
A_North_2	Claypan	2	Ev	498	0	0	0	0	0	0	498	498	0.195
A_North_2	Claypan	3	Ev	163	206	142	140	0	0	0	651	330	0.085
A_North_2	Claypan	4	Ev	167	209	211	0	0	0	0	587	341	0.091
A_North_2	Claypan	5	Ev	274	0	0	0	0	0	0	274	274	0.059
A_North_2	Claypan	6	Ev	389	238	0	0	0	0	0	627	456	0.163
A_North_2	Claypan	7	Ev	575	346	0	0	0	0	0	921	671	0.354
A_North_2	Claypan	8	Ev	107	0	0	0	0	0	0	107	107	0.009
A_North_3	Claypan	1	Ev	666	0	0	0	0	0	0	666	666	0.348
A_North_3	Claypan	2	Ev	439	0	0	0	0	0	0	439	439	0.151
A_North_3	Claypan	3	Ev	678	0	0	0	0	0	0	678	678	0.361
A_North_3	Claypan	4	Ev	348	269	0	0	0	0	0	617	440	0.152
A_North_4	Claypan	1	Ev	417	447	457	316	0	0	0	1637	826	0.536
A_North_4	Claypan	2	Ev	484	0	0	0	0	0	0	484	484	0.184
A_North_5	Claypan	1	Ev	191	302	224	0	0	0	0	717	422	0.140
A_North_5	Claypan	2	Ev	147	196	340	0	0	0	0	683	419	0.138
A_North_5	Claypan	3	Ev	517	0	0	0	0	0	0	517	517	0.210
A_North_6	Claypan	1	Ev	197	161	217	394	338	291	0	1598	683	0.366
A_North_6	Claypan	2	Ev	158	0	0	0	0	0	0	158	158	0.020
A_North_6	Claypan	3	Ev	169	167	0	0	0	0	0	336	238	0.044
A_North_6	Claypan	4	Ev	423	0	0	0	0	0	0	423	423	0.141
A_North_6	Claypan	5	Ev	253	349	179	0	0	0	0	781	467	0.171
A_North_6	Claypan	6	Ev	211	211	250	238	265	0	0	1175	528	0.219
A_North_6	Claypan	7	Ev	156	176	461	0	0	0	0	793	518	0.210
A_North_6	Claypan	8	Ev	225	188	155	266	274	0	0	1108	506	0.201
A_North_6	Claypan	9	Ev	555	0	0	0	0	0	0	555	555	0.242
A_North_6	Claypan	10	Ev	391	0	0	0	0	0	0	391	391	0.120
A_North_6	Claypan	11	Ev	420	145	135	0	0	0	0	700	464	0.169
A_North_6	Claypan	12	Ev	168	320	172	276	200	0	0	1136	526	0.217
A_North_6	Claypan	13	Ev	426	443	0	0	0	0	0	869	615	0.297
A_North_6	Claypan	14	Ev	349	0	0	0	0	0	0	349	349	0.096
A_North_7	Claypan	1	Ev	710	0	0	0	0	0	0	710	710	0.396
A_North_7	Claypan	2	Ev	224	0	0	0	0	0	0	224	224	0.039
A_North_7	Claypan	3	Ev	102	0	0	0	0	0	0	102	102	0.008
A_North_7	Claypan	4	Ev	177	0	0	0	0	0	0	177	177	0.025
A_North_7	Claypan	5	Ev	139	161	627	0	0	0	0	927	662	0.344
A_North_7	Claypan	6	Ev	163	160	196	155	0	0	0	674	339	0.090
A_North_7	Claypan	7	Ev	988	0	0	0	0	0	0	988	988	0.767
A_North_7	Claypan	8	Ev	610	121	0	0	0	0	0	731	622	0.304
A_North_7	Claypan	9	Ev	594	0	0	0	0	0	0	594	594	0.277
A_North_7	Claypan	10	Ev	356	0	0	0	0	0	0	356	356	0.100
A_North_8	Claypan	1	Ev	410	0	0	0	0	0	0	410	410	0.132
A_North_8	Claypan	2	Ev	204	364	398	303	0	0	0	1269	651	0.333
A_North_8	Claypan	3	Ev	325	342	285	368	447	0	0	1767	799	0.502
A_North_8	Claypan	4	Ev	306	0	0	0	0	0	0	306	306	0.074
A_North_9	Claypan	1	Ev	355	0	0	0	0	0	0	355	355	0.099
A_North_9	Claypan	2	Ev	270	233	110	0	0	0	0	613	373	0.109
A_North_9	Claypan	3	Ev	455	151	0	0	0	0	0	606	479	0.181
A_North_9	Claypan	4	Ev	415	88	0	0	0	0	0	503	424	0.141
A_North_9	Claypan	5	Ev	730	0	0	0	0	0	0	730	730	0.419
A_North_9	Claypan	6	Ev	313	129	124	0	0	0	0	566	361	0.102
A_North_9	Claypan	7	Ev	851	0	0	0	0	0	0	851	851	0.569
A_South_1	Claypan	1	Ev	528	0	0	0	0	0	0	528	528	0.219
A_South_1	Claypan	2	Ev	597	611	0	0	0	0	0	1208	854	0.573
A_South_10	Claypan	1	Ev	318	0	0	0	0	0	0	318	318	0.079
A_South_10	Claypan	2	Ev	424	0	0	0	0	0	0	424	424	0.141
A_South_10	Claypan	3	Ev	364	0	0	0	0	0	0	364	364	0.104
A_South_10	Claypan	4	Ev	535	0	0	0	0	0	0	535	535	0.225
A_South_10	Claypan	5	Ev	90	0	0	0	0	0	0	90	90	0.006
A_South_11	Claypan	1	Ev	503	0	0	0	0	0	0	503	503	0.199
A_South_11	Claypan	2	Ev	285	0	0	0	0	0	0	285	285	0.064
A_South_11	Claypan	3	Ev	386	430	0	0	0	0	0	816	578	0.262
A_South_2	Claypan	1	Ev	125	85	0	0	0	0	0	210	151	0.018
A_South_2	Claypan	2	Ev	94	88	0	0	0	0	0	182	129	0.013
A_South_3	Claypan	1	Ev	252	0	0	0	0	0	0	252	252	0.050
A_South_3	Claypan	2	Ev	500	0	0	0	0	0	0	500	500	0.196
A_South_3	Claypan	3	Ev	304	358	0	0	0	0	0	662	470	0.173
A_South_3	Claypan	4	Ev	173	145	0	0	0	0	0	318	226	0.040
A_South_3	Claypan	5	Ev	316	0	0	0	0	0	0	316	316	0.078
A_South_3	Claypan	6	Ev	338	0	0	0	0	0	0	338	338	0.090
A_South_3	Claypan	7	Ev	276	241	237	0	0	0	0	754	436	0.150
A_South_3	Claypan	8	Ev	242	240	395	0	0	0	0	877	522	0.214
A_South_3	Claypan	9	Ev	398	0	0	0	0	0	0	398	398	0.124
A_South_3	Claypan	10	Ev	330	0	0	0	0	0	0	330	330	0.086
A_South_4	Claypan	1	Ev	117	183	116	0	0	0	0	416	246	0.048
A_South_4	Claypan	2	Ev	320	0	0	0	0	0	0	320	320	0.080
A_South_4	Claypan	3	Ev	270	0	0	0	0	0	0	270	270	0.057
A_South_4	Claypan	4	Ev	294	0	0	0	0	0	0	294	294	0.068
A_South_4	Claypan	5	Ev	283	0	0	0	0	0	0	283	283	0.063
A_South_4	Claypan	6	Ev	174	0	0	0	0	0	0	174	174	0.024
A_South_4	Claypan	7	Ev	162	0	0	0	0	0	0	162	162	0.021

A_South_4	Claypan	8	Ev	179	0	0	0	0	0	0	179	179	0.025
A_South_4	Claypan	9	Ev	603	0	0	0	0	0	0	603	603	0.286
A_South_5	Claypan	1	Ev	829	0	0	0	0	0	0	829	829	0.540
A_South_6	Claypan	1	Ev	440	252	608	463	0	0	0	1763	917	0.661
A_South_7	Claypan	1	Ev	216	273	65	70	61	0	0	685	366	0.105
A_South_7	Claypan	2	Ev	253	0	0	0	0	0	0	253	253	0.050
A_South_7	Claypan	3	Ev	164	287	162	81	0	0	0	694	377	0.112
A_South_7	Claypan	4	Ev	100	100	295	0	0	0	0	495	327	0.084
A_South_7	Claypan	5	Ev	261	199	0	0	0	0	0	460	328	0.085
A_South_7	Claypan	6	Ev	171	0	0	0	0	0	0	171	171	0.023
A_South_7	Claypan	7	Ev	199	0	0	0	0	0	0	199	199	0.031
A_South_7	Claypan	8	Ev	85	169	329	0	0	0	0	583	380	0.113
A_South_7	Claypan	9	Ev	228	310	0	0	0	0	0	538	385	0.116
A_South_7	Claypan	10	Ev	268	117	0	0	0	0	0	385	292	0.067
A_South_8	Claypan	1	Ev	289	294	75	135	0	0	0	793	440	0.152
A_South_8	Claypan	2	Ev	672	0	0	0	0	0	0	672	672	0.355
A_South_9	Claypan	1	Ev	763	0	0	0	0	0	0	763	763	0.457
A_South_9	Claypan	2	Ev	363	0	0	0	0	0	0	363	363	0.103
A_South_9	Claypan	3	Ev	484	468	0	0	0	0	0	952	673	0.356
A_South_9	Claypan	4	Ev	235	885	460	314	0	0	0	1894	1072	0.902
A_South_9	Claypan	5	Ev	543	0	0	0	0	0	0	543	543	0.232
B_North__9	Claypan	1	Ev	120	77	0	0	0	0	0	197	143	0.016
B_North__9	Claypan	2	Ev	104	0	0	0	0	0	0	104	104	0.008
B_North__9	Claypan	3	Ev	85	108	0	0	0	0	0	193	137	0.015
B_North__9	Claypan	4	Ev	119	124	0	0	0	0	0	243	172	0.023
B_North__9	Claypan	5	Ev	353	274	0	0	0	0	0	627	447	0.157
B_North__9	Claypan	6	Ev	125	0	0	0	0	0	0	125	125	0.012
B_North__9	Claypan	7	Ev	115	82	0	0	0	0	0	197	141	0.016
B_North__9	Claypan	8	Ev	98	92	0	0	0	0	0	190	134	0.014
B_North__9	Claypan	9	Ev	185	0	0	0	0	0	0	185	185	0.027
B_North__9	Claypan	10	Ev	102	124	0	0	0	0	0	226	161	0.020
B_North__9	Claypan	11	Ev	81	72	82	0	0	0	0	235	136	0.015
B_North__9	Claypan	12	Ev	80	95	0	0	0	0	0	175	124	0.012
B_North__9	Claypan	13	Ev	102	0	0	0	0	0	0	102	102	0.008
B_North__9	Claypan	14	Ev	380	92	176	0	0	0	0	648	429	0.144
B_North__9	Claypan	15	Ev	101	0	0	0	0	0	0	101	101	0.008
B_North__9	Claypan	16	Ev	147	0	0	0	0	0	0	147	147	0.017
B_North__9	Claypan	17	Ev	151	88	0	0	0	0	0	239	175	0.024
B_North__9	Claypan	18	Ev	89	100	0	0	0	0	0	189	134	0.014
B_North__9	Claypan	19	Ev	154	0	0	0	0	0	0	154	154	0.019
B_North__9	Claypan	20	Ev	224	253	97	0	0	0	0	574	352	0.097
B_North__9	Claypan	21	Ev	120	0	0	0	0	0	0	120	120	0.011
B_North__9	Claypan	22	Ev	145	0	0	0	0	0	0	145	145	0.017
B_North__9	Claypan	23	Ev	87	65	0	0	0	0	0	152	109	0.009
B_North__9	Claypan	24	Ev	149	0	0	0	0	0	0	149	149	0.017
B_North__9	Claypan	25	Ev	238	265	287	0	0	0	0	790	457	0.164
B_North__9	Claypan	26	Ev	101	0	0	0	0	0	0	101	101	0.008
B_North__9	Claypan	27	Ev	129	0	0	0	0	0	0	129	129	0.013
B_North__9	Claypan	28	Ev	109	0	0	0	0	0	0	109	109	0.009
B_North__9	Claypan	29	Ev	98	96	127	0	0	0	0	321	187	0.027
B_North__9	Claypan	30	Ev	108	0	0	0	0	0	0	108	108	0.009
B_North__9	Claypan	31	Ev	117	85	0	0	0	0	0	202	145	0.016
B_North_1	Claypan	1	Ev	84	82	55	63	56	0	0	340	155	0.019
B_North_1	Claypan	2	Ev	83	0	0	0	0	0	0	83	83	0.005
B_North_1	Claypan	3	Ev	57	64	0	0	0	0	0	121	86	0.006
B_North_1	Claypan	4	Ev	65	65	62	0	0	0	0	192	111	0.010
B_North_1	Claypan	5	Ev	116	69	0	0	0	0	0	185	135	0.014
B_North_1	Claypan	6	Ev	130	48	0	0	0	0	0	178	139	0.015
B_North_1	Claypan	7	Ev	109	59	0	0	0	0	0	168	124	0.012
B_North_1	Claypan	8	Ev	113	0	0	0	0	0	0	113	113	0.010
B_North_1	Claypan	9	Ev	113	81	0	0	0	0	0	194	139	0.015
B_North_1	Claypan	10	Ev	120	0	0	0	0	0	0	120	120	0.011
B_North_10	Claypan	1	Ev	222	282	0	0	0	0	0	504	359	0.101
B_North_10	Claypan	2	Ev	278	0	0	0	0	0	0	278	278	0.061
B_North_10	Claypan	3	Ev	232	0	0	0	0	0	0	232	232	0.042
B_North_10	Claypan	4	Ev	126	0	0	0	0	0	0	126	126	0.012
B_North_10	Claypan	5	Ev	115	0	0	0	0	0	0	115	115	0.010
B_North_10	Claypan	6	Ev	194	160	0	0	0	0	0	354	251	0.050
B_North_10	Claypan	7	Ev	162	198	95	0	0	0	0	455	273	0.058
B_North_10	Claypan	8	Ev	168	255	0	0	0	0	0	423	305	0.073
B_North_10	Claypan	9	Ev	119	157	0	0	0	0	0	276	197	0.030
B_North_10	Claypan	10	Ev	141	205	238	150	0	0	0	734	376	0.111
B_North_10	Claypan	11	Ev	158	354	170	0	0	0	0	682	423	0.141
B_North_10	Claypan	12	Ev	392	0	0	0	0	0	0	392	392	0.121
B_North_10	Claypan	13	Ev	144	0	0	0	0	0	0	144	144	0.016
B_North_10	Claypan	14	Ev	220	198	0	0	0	0	0	418	296	0.069
B_North_10	Claypan	15	Ev	115	261	170	0	0	0	0	546	332	0.087
B_North_11	Claypan	1	Ev	132	115	0	0	0	0	0	247	175	0.024
B_North_2	Claypan	1	Ev	149	0	0	0	0	0	0	149	149	0.017
B_North_2	Claypan	2	Ev	82	30	49	0	0	0	0	161	100	0.008
B_North_2	Claypan	3	Ev	177	216	0	0	0	0	0	393	279	0.061
B_North_2	Claypan	4	Ev	176	175	0	0	0	0	0	351	248	0.048
B_North_2	Claypan	5	Ev	225	238	104	155	0	0	0	722	377	0.112
B_North_2	Claypan	6	Ev	172	170	0	0	0	0	0	342	242	0.046
B_North_2	Claypan	7	Ev	136	158	80	109	0	0	0	483	248	0.048
B_North_2	Claypan	8	Ev	144	127	124	88	105	0	0	588	266	0.056
B_North_2	Claypan	9	Ev	244	239	0	0	0	0	0	483	342	0.092
B_North_2	Claypan	10	Ev	127	114	70	271	304	149	0	1035	471	0.174
B_North_2	Claypan	11	Ev	234	165	93	117	98	196	0	903	390	0.120
B_North_2	Claypan	12	Ev	218	0	0	0	0	0	0	218	218	0.037
B_North_2	Claypan	13	Ev	150	130	199	0	0	0	0	479	281	0.062
B_North_3	Claypan	1	Ev	111	94	83	60	0	0	0	348	178	0.025
B_North_3	Claypan	2	Ev	124	103	40	0	0	0	0	267	166	0.022
B_North_3	Claypan	3	Ev	113	0	0	0	0	0	0	113	113	0.010
B_North_3	Claypan	4	Ev	143	0	0	0	0	0	0	143	143	0.016
B_North_3	Claypan	5	Ev	100	81	0	0	0	0	0	181	129	0.013
B_North_3	Claypan	6	Ev	253	131	115	0	0	0	0	499	307	0.074
B_North_3	Claypan	7	Ev	244	131	198	0	0	0	0	573	340	0.091

B_North_3	Claypan	8	Ev	118	75	0	0	0	0	0	193	140	0.015
B_North_3	Claypan	9	Ev	110	0	0	0	0	0	0	110	110	0.010
B_North_3	Claypan	10	Ev	58	107	84	0	0	0	0	249	148	0.017
B_North_3	Claypan	11	Ev	104	0	0	0	0	0	0	104	104	0.008
B_North_3	Claypan	12	Ev	109	119	0	0	0	0	0	228	161	0.020
B_North_3	Claypan	13	Ev	100	92	0	0	0	0	0	192	136	0.015
B_North_3	Claypan	14	Ev	237	256	0	0	0	0	0	493	349	0.096
B_North_3	Claypan	17	Ev	172	239	203	127	0	0	0	741	380	0.113
B_North_3	Claypan	18	Ev	113	0	0	0	0	0	0	113	113	0.010
B_North_3	Claypan	19	Ev	96	97	0	0	0	0	0	193	136	0.015
B_North_3	Claypan	20	Ev	136	0	0	0	0	0	0	136	136	0.015
B_North_4	Claypan	1	Ev	156	79	440	0	0	0	0	675	473	0.176
B_North_4	Claypan	2	Ev	171	177	0	0	0	0	0	348	246	0.048
B_North_4	Claypan	3	Ev	452	415	0	0	0	0	0	867	614	0.296
B_North_4	Claypan	4	Ev	132	0	0	0	0	0	0	132	132	0.014
B_North_4	Claypan	5	Ev	112	43	0	0	0	0	0	155	120	0.011
B_North_4	Claypan	6	Ev	262	218	465	0	0	0	0	945	577	0.261
B_North_4	Claypan	7	Ev	117	0	0	0	0	0	0	117	117	0.011
B_North_4	Claypan	8	Ev	253	128	241	307	0	0	0	929	482	0.183
B_North_4	Claypan	9	Ev	413	0	0	0	0	0	0	413	413	0.134
B_North_4	Claypan	10	Ev	140	0	0	0	0	0	0	140	140	0.015
B_North_4	Claypan	11	Ev	171	119	0	0	0	0	0	290	208	0.034
B_North_4	Claypan	12	Ev	295	0	0	0	0	0	0	295	295	0.068
B_North_4	Claypan	13	Ev	427	263	0	0	0	0	0	690	501	0.198
B_North_4	Claypan	14	Ev	100	133	172	0	0	0	0	405	239	0.045
B_North_4	Claypan	15	Ev	364	303	304	278	0	0	0	1249	628	0.309
B_North_4	Claypan	16	Ev	125	90	112	181	0	0	0	508	263	0.054
B_North_4	Claypan	17	Ev	255	291	0	0	0	0	0	546	387	0.118
B_North_4	Claypan	18	Ev	340	0	0	0	0	0	0	340	340	0.091
B_North_4	Claypan	19	Ev	229	218	0	0	0	0	0	447	316	0.079
B_North_5	Claypan	1	Ev	118	0	0	0	0	0	0	118	118	0.011
B_North_5	Claypan	2	Ev	85	88	0	0	0	0	0	173	122	0.012
B_North_5	Claypan	3	Ev	109	95	0	0	0	0	0	204	145	0.016
B_North_5	Claypan	4	Ev	100	0	0	0	0	0	0	100	100	0.008
B_North_5	Claypan	5	Ev	101	0	0	0	0	0	0	101	101	0.008
B_North_5	Claypan	6	Ev	114	0	0	0	0	0	0	114	114	0.010
B_North_5	Claypan	7	Ev	117	0	0	0	0	0	0	117	117	0.011
B_North_5	Claypan	8	Ev	84	106	0	0	0	0	0	190	135	0.014
B_North_5	Claypan	9	Ev	73	87	0	0	0	0	0	160	114	0.010
B_North_6	Claypan	1	Ev	299	200	0	0	0	0	0	499	360	0.102
B_North_6	Claypan	2	Ev	426	390	0	0	0	0	0	816	578	0.262
B_North_6	Claypan	3	Ev	395	305	335	0	0	0	0	1035	601	0.284
B_North_6	Claypan	4	Ev	374	184	157	0	0	0	0	715	445	0.156
B_North_6	Claypan	5	Ev	200	0	0	0	0	0	0	200	200	0.031
B_North_6	Claypan	6	Ev	193	274	0	0	0	0	0	467	335	0.088
B_North_6	Claypan	7	Ev	270	0	0	0	0	0	0	270	270	0.057
B_North_6	Claypan	8	Ev	264	268	0	0	0	0	0	532	376	0.111
B_North_6	Claypan	9	Ev	223	0	0	0	0	0	0	223	223	0.039
B_North_6	Claypan	10	Ev	179	295	0	0	0	0	0	474	345	0.094
B_North_7	Claypan	1	Ev	165	157	285	0	0	0	0	607	365	0.105
B_North_7	Claypan	2	Ev	412	0	0	0	0	0	0	412	412	0.133
B_North_7	Claypan	3	Ev	226	96	72	0	0	0	0	394	256	0.051
B_North_7	Claypan	4	Ev	237	0	0	0	0	0	0	237	237	0.044
B_North_7	Claypan	5	Ev	192	216	0	0	0	0	0	408	289	0.066
B_North_7	Claypan	6	Ev	262	0	0	0	0	0	0	262	262	0.054
B_North_7	Claypan	7	Ev	108	138	0	0	0	0	0	246	175	0.024
B_North_7	Claypan	8	Ev	142	0	0	0	0	0	0	142	142	0.016
B_North_7	Claypan	9	Ev	276	358	0	0	0	0	0	634	452	0.160
B_North_7	Claypan	10	Ev	242	205	375	0	0	0	0	822	491	0.189
B_North_8	Claypan	1	Ev	83	74	105	0	0	0	0	262	153	0.018
B_North_8	Claypan	2	Ev	213	255	0	0	0	0	0	468	332	0.087
B_North_8	Claypan	3	Ev	233	90	133	303	0	0	0	759	415	0.135
B_North_8	Claypan	4	Ev	235	151	156	0	0	0	0	542	320	0.080
B_North_8	Claypan	5	Ev	170	0	0	0	0	0	0	170	170	0.023
B_North_8	Claypan	6	Ev	110	140	177	58	166	238	0	889	388	0.118
B_South_1	Claypan	1	Ev	140	0	0	0	0	0	0	140	140	0.015
B_South_1	Claypan	2	Ev	111	0	0	0	0	0	0	111	111	0.010
B_South_1	Claypan	3	Ev	106	0	0	0	0	0	0	106	106	0.009
B_South_1	Claypan	4	Ev	136	182	155	0	0	0	0	473	275	0.059
B_South_1	Claypan	5	Ev	95	190	0	0	0	0	0	285	212	0.035
B_South_1	Claypan	6	Ev	125	68	0	0	0	0	0	193	142	0.016
B_South_1	Claypan	7	Ev	114	0	0	0	0	0	0	114	114	0.010
B_South_1	Claypan	8	Ev	163	0	0	0	0	0	0	163	163	0.021
B_South_1	Claypan	9	Ev	218	110	169	73	0	0	0	570	306	0.073
B_South_1	Claypan	10	Ev	111	154	53	129	0	0	0	447	236	0.044
B_South_1	Claypan	11	Ev	88	122	99	76	45	98	96	624	243	0.046
B_South_1	Claypan	12	Ev	118	135	173	0	0	0	0	426	249	0.049
B_South_1	Claypan	13	Ev	149	220	198	0	0	0	0	567	331	0.086
B_South_1	Claypan	14	Ev	67	55	105	0	0	0	0	227	136	0.015
B_South_1	Claypan	15	Ev	100	100	0	0	0	0	0	200	141	0.016
B_South_1	Claypan	16	Ev	130	0	0	0	0	0	0	130	130	0.013
B_South_1	Claypan	17	Ev	129	122	0	0	0	0	0	251	178	0.025
B_South_10	Claypan	1	Ev	429	307	0	0	0	0	0	736	528	0.219
B_South_10	Claypan	2	Ev	93	98	112	0	0	0	0	303	175	0.024
B_South_10	Claypan	3	Ev	180	73	140	0	0	0	0	393	239	0.045
B_South_10	Claypan	4	Ev	110	132	0	0	0	0	0	242	172	0.023
B_South_10	Claypan	5	Ev	118	100	0	0	0	0	0	218	155	0.019
B_South_10	Claypan	6	Ev	197	157	0	0	0	0	0	354	252	0.050
B_South_2	Claypan	1	Ev	293	258	421	280	0	0	0	1252	639	0.320
B_South_2	Claypan	2	Ev	238	395	419	0	0	0	0	1052	623	0.305
B_South_2	Claypan	3	Ev	178	168	132	110	0	0	0	588	299	0.070
B_South_2	Claypan	4	Ev	400	172	155	300	225	194	0	1446	626	0.308
B_South_2	Claypan	5	Ev	348	206	485	0	0	0	0	1039	631	0.313
B_South_3	Claypan	1	Ev	445	352	158	160	0	0	0	1115	610	0.293
B_South_4	Claypan	1	Ev	255	201	410	160	83	0	0	1109	553	0.240
B_South_4	Claypan	2	Ev	145	134	457	253	264	270	153	1676	691	0.375
B_South_4	Claypan	3	Ev	177	307	484	188	0	0	0	1156	629	0.310
B_South_4	Claypan	4	Ev	310	207	285	84	79	0	0	965	483	0.183

B_South_5	Claypan	1	Ev	526	0	0	0	0	0	0	526	526	0.217
B_South_5	Claypan	2	Ev	274	347	242	0	0	0	0	863	504	0.200
B_South_5	Claypan	3	Ev	384	348	0	0	0	0	0	732	518	0.211
B_South_5	Claypan	4	Ev	269	677	0	0	0	0	0	946	728	0.417
B_South_6	Claypan	1	Ev	677	0	0	0	0	0	0	677	677	0.360
B_South_6	Claypan	2	Ev	340	204	164	212	0	0	0	920	479	0.180
B_South_6	Claypan	3	Ev	224	84	368	0	0	0	0	676	439	0.151
B_South_6	Claypan	4	Ev	141	117	0	0	0	0	0	258	183	0.026
B_South_6	Claypan	5	Ev	321	84	89	335	70	0	0	899	485	0.185
B_South_6	Claypan	6	Ev	241	198	199	256	0	0	0	894	450	0.159
B_South_6	Claypan	7	Ev	479	0	0	0	0	0	0	479	479	0.180
B_South_7	Claypan	1	Ev	186	232	521	0	0	0	0	939	600	0.283
B_South_7	Claypan	2	Ev	254	0	0	0	0	0	0	254	254	0.051
B_South_7	Claypan	3	Ev	250	236	150	0	0	0	0	636	375	0.111
B_South_7	Claypan	4	Ev	112	185	0	0	0	0	0	297	216	0.037
B_South_7	Claypan	5	Ev	300	0	0	0	0	0	0	300	300	0.071
B_South_7	Claypan	6	Ev	156	117	0	0	0	0	0	273	195	0.030
B_South_7	Claypan	7	Ev	163	304	405	0	0	0	0	872	532	0.222
B_South_7	Claypan	8	Ev	78	70	163	153	113	209	124	1227	428	0.144
B_South_7	Claypan	9	Ev	373	418	305	356	0	0	0	1452	730	0.419
B_South_7	Claypan	10	Ev	174	130	511	160	0	0	0	975	578	0.262
B_South_7	Claypan	11	Ev	239	364	195	282	0	0	0	1080	554	0.241
B_South_8	Claypan	1	Ev	130	78	0	0	0	0	0	208	152	0.018
B_South_8	Claypan	2	Ev	167	234	0	0	0	0	0	401	287	0.065
B_South_8	Claypan	3	Ev	460	259	290	0	0	0	0	1009	602	0.285
B_South_8	Claypan	4	Ev	189	192	0	0	0	0	0	381	269	0.057
B_South_8	Claypan	5	Ev	341	370	0	0	0	0	0	711	503	0.199
B_South_8	Claypan	6	Ev	250	254	346	0	0	0	0	850	497	0.194
B_South_9	Claypan	1	Ev	234	0	0	0	0	0	0	234	234	0.043
B_South_9	Claypan	2	Ev	150	127	204	0	0	0	0	481	283	0.063
B_South_9	Claypan	3	Ev	153	0	0	0	0	0	0	153	153	0.018
B_South_9	Claypan	4	Ev	182	242	0	0	0	0	0	424	303	0.072
B_South_9	Claypan	5	Ev	174	90	112	0	0	0	0	376	226	0.040
B_South_9	Claypan	6	Ev	100	82	0	0	0	0	0	182	129	0.013
B_South_9	Claypan	7	Ev	110	0	0	0	0	0	0	110	110	0.010
B_South_9	Claypan	8	Ev	174	95	0	0	0	0	0	269	198	0.031
B_South_9	Claypan	9	Ev	219	0	0	0	0	0	0	219	219	0.038
B_South_9	Claypan	10	Ev	84	0	0	0	0	0	0	84	84	0.006
B_South_9	Claypan	11	Ev	109	155	0	0	0	0	0	264	189	0.028
B_South_9	Claypan	12	Ev	170	0	0	0	0	0	0	170	170	0.023
B_South_9	Claypan	13	Ev	110	74	0	0	0	0	0	184	133	0.014
B_South_9	Claypan	14	Ev	140	83	122	83	75	0	0	503	232	0.042
B_South_9	Claypan	15	Ev	103	0	0	0	0	0	0	103	103	0.008
B_South_9	Claypan	16	Ev	107	0	0	0	0	0	0	107	107	0.009
B_South_9	Claypan	17	Ev	123	0	0	0	0	0	0	123	123	0.012
B_South_9	Claypan	18	Ev	108	122	96	0	0	0	0	326	189	0.028
B_South_9	Claypan	19	Ev	185	62	74	0	0	0	0	321	209	0.034
B_South_9	Claypan	20	Ev	128	197	0	0	0	0	0	325	235	0.043
B_South_9	Claypan	21	Ev	91	114	103	0	0	0	0	308	179	0.025
B_South_9	Claypan	22	Ev	304	478	95	269	215	250	125	1736	726	0.414
B_South_9	Claypan	23	Ev	698	89	85	0	0	0	0	872	709	0.395

APPENDIX T
LEAF WATER POTENTIAL MEASUREMENT DATA

Site ID	Sampling campaign	Tree ID	Species	PD LWP #1	PD LWP #2	PD LWP #3	Mean PD LWP (MPa)	MD LWP #1	MD LWP #2	MD LWP #3	Mean MD LWP (MPa)
AN	May-19	AN 1	*Eucalyptus victrix*	1.30	0.75	1.10	**-1.05**	4.20	3.00	3.80	**-3.67**
AN	May-19	AN 2	*Eucalyptus victrix*	2.00	0.73	2.00	**-1.58**	3.50	3.80	4.00	**-3.77**
AN	May-19	AN 3	*Eucalyptus victrix*	1.25	1.53	1.30	**-1.36**	3.60	4.20	4.90	**-4.23**
AN	May-19	AN 4	*Eucalyptus victrix*	0.70	0.95	0.80	**-0.82**	3.30	2.70	4.00	**-3.33**
AN	May-19	AN 5	*Eucalyptus victrix*	0.60	0.67	0.64	**-0.64**	4.20	3.60	4.20	**-4.00**
AN	May-19	AN 6	*Eucalyptus victrix*	0.80	0.40	0.90	**-0.70**	5.00	3.80	3.60	**-4.13**
AN	May-19	AN 7	*Eucalyptus victrix*	0.40	0.45	0.70	**-0.52**	4.30	4.30	4.50	**-4.37**
AN	May-19	AN 8	*Eucalyptus victrix*	1.10	1.15	0.60	**-0.95**	3.80	3.90	3.90	**-3.87**
AN	May-19	AN 9	*Eucalyptus victrix*	0.40	0.35	0.50	**-0.42**	4.10	5.10	4.20	**-4.47**
AN	May-19	AN 10	*Eucalyptus victrix*	0.90	0.70	0.75	**-0.78**	3.40	3.80	3.50	**-3.57**
AS	May-19	AS 1	*Eucalyptus victrix*	1.30	1.25	1.40	**-1.32**	4.40	3.70	4.40	**-4.17**
AS	May-19	AS 2	*Eucalyptus victrix*	1.40	1.10	1.40	**-1.30**	4.10	4.10	4.10	**-4.10**
AS	May-19	AS 3	*Eucalyptus victrix*	1.50	1.70	1.70	**-1.63**	3.40	4.00	4.70	**-4.03**
AS	May-19	AS 4	*Eucalyptus victrix*	1.20	1.40	1.60	**-1.40**	4.00	4.30	5.40	**-4.57**
AS	May-19	AS 5	*Eucalyptus victrix*	0.80	0.90	1.70	**-1.13**	3.70	3.80	4.00	**-3.83**
AS	May-19	AS 6	*Eucalyptus victrix*	1.90	1.70	1.70	**-1.77**	3.70	4.00	3.90	**-3.87**
AS	May-19	AS 7	*Eucalyptus victrix*	1.40	1.40	1.40	**-1.40**	4.20	4.30	4.30	**-4.27**
AS	May-19	AS 8	*Eucalyptus victrix*	1.40	1.30	1.40	**-1.37**	3.90	4.10	4.70	**-4.23**
AS	May-19	AS 9	*Eucalyptus victrix*	1.30	1.50	1.50	**-1.43**	4.10	4.10	4.40	**-4.20**
AS	May-19	AS 10	*Eucalyptus victrix*	1.80	1.60	2.00	**-1.80**	4.10	4.10	4.30	**-4.17**
BN	May-19	BN 1	*Eucalyptus victrix*	1.20	0.90	1.00	**-1.03**	2.40	2.90	3.70	**-3.00**
BN	May-19	BN 2	*Eucalyptus victrix*	1.00	0.80	1.00	**-0.93**	2.80	1.30	3.00	**-2.37**
BN	May-19	BN 3	*Eucalyptus victrix*	1.30	1.20	1.40	**-1.30**	2.50	2.60	2.00	**-2.37**
BN	May-19	BN 4	*Eucalyptus victrix*	0.30	0.90	1.00	**-0.73**	3.70	3.70	3.80	**-3.73**
BN	May-19	BN 5	*Eucalyptus victrix*	1.30	1.40	1.50	**-1.40**	2.40	3.60	3.50	**-3.17**
BN	May-19	BN 6	*Eucalyptus victrix*	1.00	1.00	1.10	**-1.03**	3.40	3.70	3.70	**-3.60**
BN	May-19	BN 7	*Eucalyptus victrix*	1.10	1.10	1.40	**-1.20**	3.70	3.90	3.80	**-3.80**
BN	May-19	BN 8	*Eucalyptus victrix*	0.90	1.00	1.20	**-1.03**	2.90	3.70	3.60	**-3.40**
BN	May-19	BN 9	*Eucalyptus victrix*	0.80	0.60	1.00	**-0.80**	3.90	3.90	3.90	**-3.90**
BN	May-19	BN 10	*Eucalyptus victrix*	0.40	0.60	0.90	**-0.63**	4.00	3.20	2.20	**-3.13**
BS	May-19	BS 1	*Eucalyptus victrix*	0.40	0.80	0.50	**-0.57**	3.60	3.50	3.60	**-3.57**
BS	May-19	BS 2	*Eucalyptus victrix*	0.60	0.70	0.80	**-0.70**	4.00	3.90	3.70	**-3.87**
BS	May-19	BS 3	*Eucalyptus victrix*	0.40	0.50	0.80	**-0.57**	4.10	4.30	4.10	**-4.17**
BS	May-19	BS 4	*Eucalyptus victrix*	1.00	0.90	1.00	**-0.97**	4.30	4.30	4.40	**-4.33**
BS	May-19	BS 5	*Eucalyptus victrix*	1.50	1.50	1.70	**-1.57**	4.20	4.20	4.30	**-4.23**
BS	May-19	BS 6	*Eucalyptus victrix*	0.50	0.70	0.70	**-0.63**	3.30	3.10	3.10	**-3.17**
BS	May-19	BS 7	*Eucalyptus victrix*	0.20	0.20	0.20	**-0.20**	4.00	3.80	3.90	**-3.90**
BS	May-19	BS 8	*Eucalyptus victrix*	0.40	0.40	0.20	**-0.33**	3.30	3.70	3.60	**-3.53**
BS	May-19	BS 9	*Eucalyptus victrix*	0.40	0.50	0.50	**-0.47**	5.70	5.10	6.20	**-5.67**
BS	May-19	BS 10	*Eucalyptus victrix*	0.50	0.30	0.40	**-0.40**	4.00	4.00	4.40	**-4.13**
AN	Oct-19	AN 1	*Eucalyptus victrix*	1.00	0.90	1.00	**-0.97**	3.90	4.60	5.20	**-4.57**
AN	Oct-19	AN 2	*Eucalyptus victrix*	1.50	1.30	1.40	**-1.40**	4.10	3.80	3.10	**-3.67**
AN	Oct-19	AN 3	*Eucalyptus victrix*	1.20	1.10	0.90	**-1.07**	4.60	5.20	5.90	**-5.23**
AN	Oct-19	AN 4	*Eucalyptus victrix*	0.50	0.60	0.60	**-0.57**	4.10	2.70	4.20	**-3.67**
AN	Oct-19	AN 5	*Eucalyptus victrix*	0.60	0.50	0.40	**-0.50**	4.40	4.00	5.10	**-4.50**

AN	Oct-19	AN 6	*Eucalyptus victrix*	0.80	0.90	0.80	**-0.83**	3.70	4.40	4.00	**-4.03**
AN	Oct-19	AN 7	*Eucalyptus victrix*	0.60	0.70	0.80	**-0.70**	5.10	5.50	5.30	**-5.30**
AN	Oct-19	AN 8	*Eucalyptus victrix*	1.10	1.10	1.00	**-1.07**	4.40	4.80	4.30	**-4.50**
AN	Oct-19	AN 9	*Eucalyptus victrix*	0.70	0.50	0.70	**-0.63**	5.30	3.50	6.30	**-5.03**
AN	Oct-19	AN 10	*Eucalyptus victrix*	0.80	0.80	0.70	**-0.77**	2.10	4.00	4.60	**-3.57**
AS	Oct-19	AS 1	*Eucalyptus victrix*	1.60	1.40	1.40	**-1.47**	4.00	4.30	4.60	**-4.30**
AS	Oct-19	AS 2	*Eucalyptus victrix*	1.10	1.10	0.80	**-1.00**	4.30	4.30	4.40	**-4.33**
AS	Oct-19	AS 3	*Eucalyptus victrix*	1.00	1.20	1.00	**-1.07**	4.30	4.20	4.80	**-4.43**
AS	Oct-19	AS 4	*Eucalyptus victrix*	1.10	1.50	1.40	**-1.33**	4.90	5.40	5.90	**-5.40**
AS	Oct-19	AS 5	*Eucalyptus victrix*	1.30	1.70	1.50	**-1.50**	4.50	4.80	4.60	**-4.63**
AS	Oct-19	AS 6	*Eucalyptus victrix*	1.90	1.90	1.80	**-1.87**	4.70	4.80	4.80	**-4.77**
AS	Oct-19	AS 7	*Eucalyptus victrix*	0.90	1.30	1.50	**-1.23**	4.60	4.80	4.80	**-4.73**
AS	Oct-19	AS 8	*Eucalyptus victrix*	1.70	1.70	0.90	**-1.43**	4.80	5.00	4.70	**-4.83**
AS	Oct-19	AS 9	*Eucalyptus victrix*	1.40	1.70	1.50	**-1.53**	4.30	4.80	5.00	**-4.70**
AS	Oct-19	AS 10	*Eucalyptus victrix*	2.10	2.10	2.20	**-2.13**	5.80	5.30	5.60	**-5.57**
BN	Oct-19	BN 1	*Eucalyptus victrix*	0.80	1.20	1.00	**-1.00**	3.50	3.20	3.10	**-3.27**
BN	Oct-19	BN 2	*Eucalyptus victrix*	1.50	1.30	0.80	**-1.20**	3.80	3.60	2.80	**-3.40**
BN	Oct-19	BN 3	*Eucalyptus victrix*	1.00	0.90	1.40	**-1.10**	4.70	4.10	3.20	**-4.00**
BN	Oct-19	BN 4	*Eucalyptus victrix*	0.30	0.60	0.50	**-0.47**	2.40	5.10	4.70	**-4.07**
BN	Oct-19	BN 5	*Eucalyptus victrix*	0.70	0.60	0.70	**-0.67**	4.10	3.90	3.80	**-3.93**
BN	Oct-19	BN 6	*Eucalyptus victrix*	1.10	0.90	1.30	**-1.10**	3.90	3.20	3.90	**-3.67**
BN	Oct-19	BN 7	*Eucalyptus victrix*	0.60	0.90	1.10	**-0.87**	4.60	4.50	4.40	**-4.50**
BN	Oct-19	BN 8	*Eucalyptus victrix*	0.70	1.10	1.20	**-1.00**	3.00	4.00	4.40	**-3.80**
BN	Oct-19	BN 9	*Eucalyptus victrix*	0.30	0.50	0.70	**-0.50**	4.20	4.60	4.30	**-4.37**
BN	Oct-19	BN 10	*Eucalyptus victrix*	0.50	0.60	0.70	**-0.60**	4.10	3.00	4.80	**-3.97**
BS	Oct-19	BS 1	*Eucalyptus victrix*	0.30	0.50	0.80	**-0.53**	3.40	3.30	3.40	**-3.37**
BS	Oct-19	BS 2	*Eucalyptus victrix*	0.50	0.60	0.90	**-0.67**	3.60	3.80	3.70	**-3.70**
BS	Oct-19	BS 3	*Eucalyptus victrix*	1.70	1.50	1.30	**-1.50**	3.90	3.00	3.90	**-3.60**
BS	Oct-19	BS 4	*Eucalyptus victrix*	1.70	2.10	2.10	**-1.97**	4.80	3.70	3.40	**-3.97**
BS	Oct-19	BS 5	*Eucalyptus victrix*	1.70	1.60	1.50	**-1.60**	3.10	3.10	3.60	**-3.27**
BS	Oct-19	BS 6	*Eucalyptus victrix*	0.80	0.20	0.10	**-0.37**	3.50	3.90	3.90	**-3.77**
BS	Oct-19	BS 7	*Eucalyptus victrix*	0.50	0.80	0.50	**-0.60**	3.80	3.80	3.80	**-3.80**
BS	Oct-19	BS 8	*Eucalyptus victrix*	0.20	0.50	0.40	**-0.37**	6.90	4.70	6.10	**-5.90**
BS	Oct-19	BS 9	*Eucalyptus victrix*	0.50	0.60	0.80	**-0.63**	3.20	3.50	2.90	**-3.20**
BS	Oct-19	BS 10	*Eucalyptus victrix*	0.60	0.50	0.60	**-0.57**	3.60	2.60	3.90	**-3.37**
AN	Oct-21	AN1	*Eucalyptus victrix*	-1.25	-1.29	-1.86	**-1.47**	-4.31	-3.52	-3.52	**-3.78**
AN	Oct-21	AN2	*Eucalyptus victrix*	-1.13	-1.21	-1.50	**-1.28**	-4.41	-4.65	-4.24	**-4.43**
AN	Oct-21	AN3	*Eucalyptus victrix*	-1.65	-1.77	-2.06	**-1.83**	-4.43	-4.02	-4.79	**-4.41**
AN	Oct-21	AN4	*Eucalyptus victrix*	-1.16	-0.63	-0.81	**-0.87**	-4.20	-4.55	-2.65	**-3.80**
AN	Oct-21	AN5	*Eucalyptus victrix*	-1.11	-1.19	-1.24	**-1.18**	-2.98	-2.80	-3.15	**-2.98**
AN	Oct-21	AN6	*Eucalyptus victrix*	-1.07	-1.04	-1.34	**-1.15**	-4.17	-3.91	-4.00	**-4.03**
AN	Oct-21	AN7	*Eucalyptus victrix*	-0.79	-0.98	-0.77	**-0.85**	-5.95	-5.72	-5.24	**-5.64**
AN	Oct-21	AN8	*Eucalyptus victrix*	-1.10	-0.99	-1.06	**-1.05**	-4.49	-5.19	-4.17	**-4.62**
AN	Oct-21	AN9	*Eucalyptus victrix*	-1.13	-1.08	-1.05	**-1.09**	-4.61	-3.23	-5.59	**-4.48**
AN	Oct-21	AN10	*Eucalyptus victrix*	-1.06	-1.23	-1.04	**-1.11**	-3.64	-4.19	-4.37	**-4.07**
AS	Oct-21	AS1	*Eucalyptus victrix*	-2.47	-2.29	-2.18	**-2.31**	-4.21	-4.35	-3.95	**-4.17**
AS	Oct-21	AS2	*Eucalyptus victrix*	-1.82	-1.54	-1.67	**-1.68**	-4.60	-3.53	-3.91	**-4.01**

AS	Oct-21	AS3	*Eucalyptus victrix*	-1.59	-1.67	-1.38	**-1.55**	-4.01	-3.89	-2.42	**-3.44**
AS	Oct-21	AS4	*Eucalyptus victrix*	-1.52	-1.85	-1.51	**-1.63**	-4.36	-4.81	-6.06	**-5.08**
AS	Oct-21	AS5	*Eucalyptus victrix*	-1.53	-1.79	-1.73	**-1.68**	-4.10	-3.08	-4.23	**-3.80**
AS	Oct-21	AS6	*Eucalyptus victrix*	-2.01	-1.88	-1.98	**-1.96**	-4.61	-4.66	-4.01	**-4.43**
AS	Oct-21	AS7	*Eucalyptus victrix*	-1.49	-1.64	-1.70	**-1.61**	-4.51	-3.37	-4.34	**-4.07**
AS	Oct-21	AS8	*Eucalyptus victrix*	-1.48	-2.11	-1.85	**-1.81**	-2.75	-4.29	-5.59	**-4.21**
AS	Oct-21	AS9	*Eucalyptus victrix*	-1.45	-1.46	-1.51	**-1.47**	-4.18	-3.62	-5.16	**-4.32**
AS	Oct-21	AS10	*Eucalyptus victrix*	-1.56	-1.93	-2.02	**-1.84**	-5.44	-2.91	-3.95	**-4.10**
BN	Oct-21	BN1	*Eucalyptus victrix*	-1.60	-1.78	-1.73	**-1.70**	-3.92	-3.94	-3.43	**-3.76**
BN	Oct-21	BN2	*Eucalyptus victrix*	-1.22	-1.91	-1.82	**-1.65**	-3.56	-4.83	-3.88	**-4.09**
BN	Oct-21	BN3	*Eucalyptus victrix*	-1.66	-1.75	-1.83	**-1.75**	-2.32	-3.14	-4.56	**-3.34**
BN	Oct-21	BN4	*Eucalyptus victrix*	-0.85	-0.96	-1.06	**-0.96**	-3.15	-3.22	-3.45	**-3.27**
BN	Oct-21	BN5	*Eucalyptus victrix*	-1.80	-1.61	-1.48	**-1.63**	-3.68	-3.06	-2.73	**-3.16**
BN	Oct-21	BN6	*Eucalyptus victrix*	-0.94	-1.72	-1.10	**-1.25**	-4.68	-3.78	-2.73	**-3.73**
BN	Oct-21	BN7	*Eucalyptus victrix*	-1.58	-1.35	-1.24	**-1.39**	-3.62	-4.55	-4.14	**-4.10**
BN	Oct-21	BN8	*Eucalyptus victrix*	-1.18	-1.18	-1.26	**-1.21**	-1.92	-3.47	-3.30	**-2.90**
BN	Oct-21	BN9	*Eucalyptus victrix*	-1.15	-1.54	-1.58	**-1.42**	-3.16	-4.34	-4.41	**-3.97**
BN	Oct-21	BN10	*Eucalyptus victrix*	-1.46	-1.08	-1.12	**-1.22**	-3.80	-4.41	-3.87	**-4.03**
BS	Oct-21	BS1	*Eucalyptus victrix*	-1.50	-1.19	-1.38	**-1.36**	-3.67	-3.38	-3.44	**-3.50**
BS	Oct-21	BS2	*Eucalyptus victrix*	-0.89	-1.03	-0.89	**-0.94**	-4.12	-3.88	-4.24	**-4.08**
BS	Oct-21	BS3	*Eucalyptus victrix*	-0.76	-0.76	-0.90	**-0.81**	-4.11	-4.01	-3.87	**-4.00**
BS	Oct-21	BS4	*Eucalyptus victrix*	-2.01	-1.65	-2.15	**-1.94**	-3.40	-4.02	-4.63	**-4.02**
BS	Oct-21	BS5	*Eucalyptus victrix*	-1.74	-2.01	-1.57	**-1.77**	-3.48	-4.29	-4.57	**-4.11**
BS	Oct-21	BS6	*Eucalyptus victrix*	-1.08	-1.23	-1.04	**-1.12**	-5.92	-5.79	-3.50	**-5.07**
BS	Oct-21	BS7	*Eucalyptus victrix*	-1.24	-0.91	-0.82	**-0.99**	-3.63	-4.27	-3.96	**-3.95**
BS	Oct-21	BS8	*Eucalyptus victrix*	-0.67	-0.98	-0.72	**-0.79**	-2.39	-4.20	-3.94	**-3.51**
BS	Oct-21	BS9	*Eucalyptus victrix*	-1.09	-1.10	-0.60	**-0.93**	-4.76	-3.56	-4.34	**-4.22**
BS	Oct-21	BS10	*Eucalyptus victrix*	-0.62	-0.95	-1.09	**-0.89**	-4.22	-2.97	-4.58	**-3.92**
AE	Oct-21	AE1	*Eucalyptus victrix*	-1.13	-2.15	-1.48	**-1.59**	-4.39	-4.35	-5.90	**-4.88**
AE	Oct-21	AE2	*Eucalyptus victrix*	-1.71	-0.93	-1.12	**-1.25**	-4.23	-4.65	-3.59	**-4.16**
AE	Oct-21	AE3	*Eucalyptus victrix*	-1.12	-1.24	-1.15	**-1.17**	-5.01	-4.73	-5.03	**-4.92**
AE	Oct-21	AE4	*Eucalyptus victrix*	-1.39	-0.99	-1.65	**-1.34**	-4.25	-4.12	-4.30	**-4.22**
AE	Oct-21	AE5	*Eucalyptus victrix*	-2.52	-1.44	-1.16	**-1.71**	-4.36	-3.64	-4.44	**-4.15**
AE	Oct-21	AE6	*Eucalyptus victrix*	-1.46	-1.81	-1.90	**-1.72**	-4.23	-4.67	-3.79	**-4.23**
AE	Oct-21	AE7	*Eucalyptus victrix*	-1.14	-1.00	-0.92	**-1.02**	-3.19	-3.95	-3.41	**-3.52**
AE	Oct-21	AE8	*Eucalyptus victrix*	-1.58	-1.63	-1.56	**-1.59**	-4.63	-4.73	-3.84	**-4.40**
AE	Oct-21	AE9	*Eucalyptus victrix*	-1.24	-1.52	-1.04	**-1.27**	-4.55	-3.42	-3.12	**-3.70**
AE	Oct-21	AE10	*Eucalyptus victrix*	-1.04	-1.29	-1.49	**-1.27**	-4.35	-4.62	-4.75	**-4.57**
AW	Oct-21	AW1	*Eucalyptus victrix*	-1.01	-0.85	-0.88	**-0.91**	-4.42	-4.25	-4.06	**-4.24**
AW	Oct-21	AW2	*Eucalyptus victrix*	-1.14	-1.39	-1.03	**-1.19**	-5.75	-5.82	-4.86	**-5.48**
AW	Oct-21	AW3	*Eucalyptus victrix*	-1.74	-1.34	-1.42	**-1.50**	-4.59	-3.66	-4.91	**-4.39**
AW	Oct-21	AW4	*Eucalyptus victrix*	-0.73	-0.83	-0.85	**-0.80**	-4.19	-3.75	-2.65	**-3.53**
AW	Oct-21	AW5	*Eucalyptus victrix*	-1.34	-1.23	-1.51	**-1.36**	-4.50	-6.03	-4.78	**-5.10**
AW	Oct-21	AW6	*Eucalyptus victrix*	-1.45	-1.22	-1.51	**-1.39**	-3.28	-3.62	-3.18	**-3.36**
AW	Oct-21	AW7	*Eucalyptus victrix*	-1.43	-1.47	-1.82	**-1.57**	-4.52	-4.70	-4.55	**-4.59**
AW	Oct-21	AW8	*Eucalyptus victrix*	-1.61	-1.98	-1.42	**-1.67**	-4.20	-4.17	-4.49	**-4.29**
AW	Oct-21	AW9	*Eucalyptus victrix*	-1.06	-1.21	-1.13	**-1.13**	-4.73	-3.13	-5.42	**-4.43**

AW	Oct-21	AW10	*Eucalyptus victrix*	-1.45	-1.01	-1.48	**-1.31**	-4.42	-3.77	-3.42	**-3.87**
CN	Oct-21	CN1	*Eucalyptus victrix*	-0.94	-0.77		**-0.86**	-2.69	-3.38		**-3.04**
CN	Oct-21	CN2	*Atalaya hemiglauca*	-1.35	-1.44		**-1.40**	-3.35	-2.94		**-3.15**
CN	Oct-21	CN3	*Melaleuca glomerata*	-1.20	-1.06		**-1.13**	-2.89	-3.34		**-3.12**
CN	Oct-21	CN4	*Eucalyptus victrix*	-0.79	-0.62		**-0.71**	-3.38	-3.07		**-3.23**
CN	Oct-21	CN5	*Melaleuca glomerata*	-1.64			**-1.64**	-3.52	-3.66		**-3.59**
CN	Oct-21	CN6	*Melaleuca glomerata*	-1.68	-1.46		**-1.57**	-3.72	-4.22		**-3.97**
CN	Oct-21	CN7	*Eucalyptus victrix*	-2.67	-1.87		**-2.27**	-4.30	-3.46		**-3.88**
CN	Oct-21	CN8	*Eucalyptus victrix*	-1.42	-1.26		**-1.34**	-3.82	-5.09		**-4.46**
CN	Oct-21	CN9	*Atalaya hemiglauca*	-1.87	-1.02		**-1.45**	-2.95	-2.61		**-2.78**
CN	Oct-21	CN10	*Melaleuca glomerata*	-1.72	-1.97		**-1.85**	-3.18	-2.97		**-3.08**
CN	Oct-21	CN11	*Atalaya hemiglauca*	-1.19	-1.46		**-1.33**	-3.13	-3.29		**-3.21**
CN	Oct-21	CN12	*Atalaya hemiglauca*	-0.92	-1.92		**-1.42**	-3.22	-2.81		**-3.02**
CN	Oct-21	CN13	*Acacia ampliceps*	-0.81	-0.67		**-0.74**	-2.43	-1.85		**-2.14**
CN	Oct-21	CN14	*Acacia ampliceps*	-1.48	-1.46		**-1.47**	-3.20	-3.04		**-3.12**
CN	Oct-21	CN15	*Eucalyptus victrix*	-1.03	-1.24		**-1.14**	-3.05	-3.03		**-3.04**
CN	Oct-21	CN16	*Atalaya hemiglauca*	-1.13	-1.43		**-1.28**	-2.36	-2.87		**-2.62**
CN	Oct-21	CN17	*Melaleuca glomerata*	-2.49	-1.73		**-2.11**	-3.71	-4.17		**-3.94**
CN	Oct-21	CN18	*Acacia ampliceps*	-1.31	-1.42		**-1.37**	-2.75	-2.72		**-2.74**
CN	Oct-21	CN19	*Acacia ampliceps*	-1.05	-1.38		**-1.22**	-2.94	-2.79		**-2.87**
CN	Oct-21	CN20	*Acacia ampliceps*	-0.40	-1.34		**-0.87**	-2.65	-1.60		**-2.13**
CS	Oct-21	CS1	*Eucalyptus victrix*	-1.32	-1.12		**-1.22**	-3.90	-4.78		**-4.34**
CS	Oct-21	CS2	*Eucalyptus victrix*	-1.92	-1.93		**-1.93**	-4.79	-4.64		**-4.72**
CS	Oct-21	CS3	*Eucalyptus victrix*	-0.91	-1.20		**-1.06**	-3.72	-4.45		**-4.09**
CS	Oct-21	CS4	*Eucalyptus victrix*	-1.69	-1.07		**-1.38**	-3.79	-3.53		**-3.66**
CS	Oct-21	CS5	*Eucalyptus victrix*	-1.50	-1.95		**-1.73**	-4.10	-4.00		**-4.05**
CS	Oct-21	CS6	*Eucalyptus victrix*	-1.21	-1.44		**-1.33**	-4.19	-4.12		**-4.16**
CS	Oct-21	CS7	*Eucalyptus victrix*	-0.98	-1.02		**-1.00**	-4.48	-3.45		**-3.97**
CS	Oct-21	CS8	*Eucalyptus victrix*	-2.73	-1.56		**-2.15**	-4.16	-4.42		**-4.29**
CS	Oct-21	CS9	*Eucalyptus victrix*	-1.05	-0.90		**-0.98**	-4.25	-5.21		**-4.73**
CS	Oct-21	CS10	*Eucalyptus victrix*	-1.01	-1.02		**-1.02**	-3.48	-2.76		**-3.12**
AN	Oct-22	AN1	*Eucalyptus victrix*	-1.60	-1.70		**-1.65**	-4.10	-3.80		**-3.95**
AN	Oct-22	AN2	*Eucalyptus victrix*	-1.45	-1.30		**-1.38**	-3.40	-4.30	-4.10	**-3.93**
AN	Oct-22	AN3	*Eucalyptus victrix*	-1.20	-1.35		**-1.28**	-4.10	-4.60		**-4.35**
AN	Oct-22	AN4	*Eucalyptus victrix*	-1.50	-1.15		**-1.33**	-3.20	-3.50		**-3.35**
AN	Oct-22	AN5	*Eucalyptus victrix*	-0.85	-0.70		**-0.78**	-3.20	-3.20		**-3.20**
AN	Oct-22	AN6	*Eucalyptus victrix*	-0.70	-1.00		**-0.85**	-3.40	-3.60		**-3.50**
AN	Oct-22	AN7	*Eucalyptus victrix*	-1.25	-1.05		**-1.15**	-3.15	-4.25	-4.10	**-3.83**
AN	Oct-22	AN8	*Eucalyptus victrix*	-1.60	-1.80		**-1.70**	-3.95	-3.90		**-3.93**
AN	Oct-22	AN9	*Eucalyptus victrix*	-1.30	-1.10		**-1.20**	-2.95	-4.10	-3.50	**-3.52**
AN	Oct-22	AN10	*Eucalyptus victrix*	-1.65	-1.70		**-1.68**	-3.45	-4.15	-2.80	**-3.47**
AS	Oct-22	AS1	*Eucalyptus victrix*	-1.50	-1.55		**-1.53**	-3.65	-4.40	-4.70	**-4.25**
AS	Oct-22	AS2	*Eucalyptus victrix*	-1.30	-1.45		**-1.38**	-3.95	-3.90		**-3.93**
AS	Oct-22	AS3	*Eucalyptus victrix*	-1.60	-1.75		**-1.68**	-3.05	-4.20	-4.10	**-3.78**
AS	Oct-22	AS4	*Eucalyptus victrix*	-1.45	-1.50		**-1.48**	-4.30	-4.90		**-4.60**
AS	Oct-22	AS5	*Eucalyptus victrix*	-2.30	-1.70	-1.75	**-1.92**	-3.90	-3.80		**-3.85**
AS	Oct-22	AS6	*Eucalyptus victrix*	-2.20	-2.30		**-2.25**	-3.60	-3.50		**-3.55**

AS	Oct-22	AS7	*Eucalyptus victrix*	-2.20	-2.20		**-2.20**	-4.60	-4.55		**-4.58**
AS	Oct-22	AS8	*Eucalyptus victrix*	-2.05	-2.05		**-2.05**	-3.60	-3.90		**-3.75**
AS	Oct-22	AS9	*Eucalyptus victrix*	-2.65	-2.20		**-2.43**	-4.10	-4.20		**-4.15**
AS	Oct-22	AS10	*Eucalyptus victrix*	-2.10	-2.35		**-2.23**	-4.30	-4.80		**-4.55**
BN	Oct-22	BN1	*Eucalyptus victrix*	-1.70	-1.80		**-1.75**	-3.40	-3.35		**-3.38**
BN	Oct-22	BN2	*Eucalyptus victrix*	-1.85	-1.70		**-1.78**	-4.10	-3.95		**-4.03**
BN	Oct-22	BN3	*Eucalyptus victrix*	-1.80	-2.05		**-1.93**	-3.85	-4.10		**-3.98**
BN	Oct-22	BN4	*Eucalyptus victrix*	-1.50	-1.30		**-1.40**	-3.20	-3.50		**-3.35**
BN	Oct-22	BN5	*Eucalyptus victrix*	-1.70	-1.45		**-1.58**	-3.30	-3.65		**-3.48**
BN	Oct-22	BN6	*Eucalyptus victrix*	-1.60	-1.90		**-1.75**	-4.20	-4.10		**-4.15**
BN	Oct-22	BN7	*Eucalyptus victrix*	-1.40	-1.30		**-1.35**	-3.70	-3.85		**-3.78**
BN	Oct-22	BN8	*Eucalyptus victrix*	-1.35	-1.45		**-1.40**	-3.75	-3.10	-4.00	**-3.62**
BN	Oct-22	BN9	*Eucalyptus victrix*	-1.50	-1.50		**-1.50**	-3.15	-3.80		**-3.48**
BN	Oct-22	BN10	*Eucalyptus victrix*	-1.20	-1.30		**-1.25**	-3.25	-3.15		**-3.20**
BS	Oct-22	BS1	*Eucalyptus victrix*	-1.60	-1.25		**-1.43**	-3.90	-3.65		**-3.78**
BS	Oct-22	BS2	*Eucalyptus victrix*	-1.45	-1.30		**-1.38**	-2.80	-3.60	-3.85	**-3.42**
BS	Oct-22	BS3	*Eucalyptus victrix*	-1.15	-1.20		**-1.18**	-3.70	-3.60		**-3.65**
BS	Oct-22	BS4	*Eucalyptus victrix*	-2.50	-2.80		**-2.65**	-3.90	-3.95		**-3.93**
BS	Oct-22	BS5	*Eucalyptus victrix*	-2.10	-2.00		**-2.05**	-3.25	-3.55		**-3.40**
BS	Oct-22	BS6	*Eucalyptus victrix*	-1.90			**-1.90**	-3.10			**-3.10**
BS	Oct-22	BS7	*Eucalyptus victrix*	-1.60	-1.20		**-1.40**	-3.15	-4.35	-3.70	**-3.73**
BS	Oct-22	BS8	*Eucalyptus victrix*	-1.30	-1.40		**-1.35**	-4.00	-4.15		**-4.08**
BS	Oct-22	BS9	*Eucalyptus victrix*	-1.25	-1.60		**-1.43**	-4.20	-3.85		**-4.03**
BS	Oct-22	BS10	*Eucalyptus victrix*	-1.50	-1.45		**-1.48**	-3.40	-3.45		**-3.43**
AE	Oct-22	AE1	*Eucalyptus victrix*	-1.70	-1.60		**-1.65**	-2.40	-3.70	-3.80	**-3.30**
AE	Oct-22	AE2	*Eucalyptus victrix*	-1.70	-1.60		**-1.65**	-2.90	-3.40		**-3.15**
AE	Oct-22	AE3	*Eucalyptus victrix*	-2.00	-2.20		**-2.10**	-2.70	-3.50		**-3.10**
AE	Oct-22	AE4	*Eucalyptus victrix*	-1.30	-1.25		**-1.28**	-3.30	-3.35		**-3.33**
AE	Oct-22	AE5	*Eucalyptus victrix*	-1.40	-1.60		**-1.50**	-3.30	-3.40		**-3.35**
AE	Oct-22	AE6	*Eucalyptus victrix*	-1.50	-1.80		**-1.65**	-3.20	-3.35		**-3.28**
AE	Oct-22	AE7	*Eucalyptus victrix*	-1.35	-1.40		**-1.38**	-4.20	-4.10		**-4.15**
AE	Oct-22	AE8	*Eucalyptus victrix*	-1.40	-1.30		**-1.35**	-3.50	-3.80		**-3.65**
AE	Oct-22	AE9	*Eucalyptus victrix*	tree unable to be sampled in 2022							
AE	Oct-22	AE10	*Eucalyptus victrix*	-1.20	-1.30		**-1.25**	-3.35	-3.40		**-3.38**
AW	Oct-22	AW1	*Eucalyptus victrix*	-1.20	-0.95		**-1.08**	-4.00	-3.90		**-3.95**
AW	Oct-22	AW2	*Eucalyptus victrix*	-1.40	-1.55		**-1.48**	-2.30	-2.70		**-2.50**
AW	Oct-22	AW3	*Eucalyptus victrix*	-0.85	-0.90		**-0.88**	-3.20	-3.40		**-3.30**
AW	Oct-22	AW4	*Eucalyptus victrix*	-1.25	-1.30		**-1.28**	-3.30	-2.80		**-3.05**
AW	Oct-22	AW5	*Eucalyptus victrix*	-1.00	-1.05		**-1.03**	-3.50	-2.90	-4.20	**-3.53**
AW	Oct-22	AW6	*Eucalyptus victrix*	-1.10	-1.30		**-1.20**	-4.00	-3.20	-2.70	**-3.30**
AW	Oct-22	AW7	*Eucalyptus victrix*	-1.10	-1.10		**-1.10**	-2.75	-3.50		**-3.13**
AW	Oct-22	AW8	*Eucalyptus victrix*	-1.00	-0.95		**-0.98**	-3.90	-4.10		**-4.00**
AW	Oct-22	AW9	*Eucalyptus victrix*	-1.60	-1.60		**-1.60**	-2.90	-2.90		**-2.90**
AW	Oct-22	AW10	*Eucalyptus victrix*	tree unable to be relocated							
CN	Oct-22	CN1	*Eucalyptus victrix*	-1.20	-1.25		**-1.23**	-3.95	-3.60		**-3.78**
CN	Oct-22	CN2	*Atalaya hemiglauca*	-1.60	-1.70		**-1.65**	-2.60	-2.50		**-2.55**
CN	Oct-22	CN3	*Melaleuca glomerata*	-1.60	-1.70		**-1.65**	-3.20	-3.05		**-3.13**

CN	Oct-22	CN4	*Eucalyptus victrix*	-1.10	-1.25		**-1.18**	-2.60	-4.80	-4.20	**-3.87**
CN	Oct-22	CN5	*Melaleuca glomerata*	-2.00	-1.95		**-1.98**	-3.70	-3.40		**-3.55**
CN	Oct-22	CN6	*Melaleuca glomerata*	-2.00	-1.95		**-1.98**	-4.60	-3.80	-3.50	**-3.97**
CN	Oct-22	CN7	*Eucalyptus victrix*	-1.80	-1.85		**-1.83**	-3.65	-4.10		**-3.88**
CN	Oct-22	CN8	*Eucalyptus victrix*	-1.75	-1.70		**-1.73**	-3.10	-2.95		**-3.03**
CN	Oct-22	CN9	*Atalaya hemiglauca*	-1.70	-1.80		**-1.75**	-2.80	-2.50		**-2.65**
CN	Oct-22	CN10	*Melaleuca glomerata*	-1.70	-1.80		**-1.75**	-3.60	-3.45		**-3.53**
CN	Oct-22	CN11	*Atalaya hemiglauca*	-2.40	-2.30		**-2.35**	-3.10	-2.70		**-2.90**
CN	Oct-22	CN12	*Atalaya hemiglauca*	-2.50	-2.50		**-2.50**	-3.25	-2.95		**-3.10**
CN	Oct-22	CN13	*Acacia ampliceps*	tree was dead in 2022							
CN	Oct-22	CN14	*Acacia ampliceps*	-1.60	-1.45		**-1.53**	-3.15	-3.10		**-3.13**
CN	Oct-22	CN15	*Eucalyptus victrix*	-0.80	-1.80	-1.70	**-1.43**	-3.60	-3.90		**-3.75**
CN	Oct-22	CN16	*Atalaya hemiglauca*	-1.70	-1.75		**-1.73**	-3.05	-2.15	-2.90	**-2.70**
CN	Oct-22	CN17	*Melaleuca glomerata*	-2.20	-2.05		**-2.13**	-3.80	-3.95		**-3.88**
CN	Oct-22	CN18	*Acacia ampliceps*	-2.20	-1.50	-1.50	**-1.73**	-2.80	-2.95		**-2.88**
CN	Oct-22	CN19	*Acacia ampliceps*	-2.00	-1.10	-2.15	**-1.75**	-3.50	-3.70		**-3.60**
CN	Oct-22	CN20	*Acacia ampliceps*	tree unable to be relocated							
CS	Oct-22	CS1	*Eucalyptus victrix*	-1.50	-1.45		**-1.48**	-4.20	-4.30		**-4.25**
CS	Oct-22	CS2	*Eucalyptus victrix*	-2.00	-1.60		**-1.80**	-3.40	-3.40		**-3.40**
CS	Oct-22	CS3	*Eucalyptus victrix*	-1.65	-1.55		**-1.60**	-4.00	-3.30	-2.70	**-3.33**
CS	Oct-22	CS4	*Eucalyptus victrix*	-2.15	-1.40	-1.45	**-1.67**	-4.05	-2.90	-3.20	**-3.38**
CS	Oct-22	CS5	*Eucalyptus victrix*	-1.45	-1.75		**-1.60**	-3.20	-3.50		**-3.35**
CS	Oct-22	CS6	*Eucalyptus victrix*	-1.60	-1.85		**-1.73**	-3.75	-4.80	-4.10	**-4.22**
CS	Oct-22	CS7	*Eucalyptus victrix*	-1.00	-1.00		**-1.00**	-4.00	-3.80		**-3.90**
CS	Oct-22	CS8	*Eucalyptus victrix*	-1.70	-1.95		**-1.83**	-3.50	-4.60	-4.35	**-4.15**
CS	Oct-22	CS9	*Eucalyptus victrix*	-1.25	-1.20		**-1.23**	-4.30	-3.35	-3.80	**-3.82**
CS	Oct-22	CS10	*Eucalyptus victrix*	-1.10	-1.15		**-1.13**	-3.70	-4.50	-4.00	**-4.07**